UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
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Study of the improvement of the illumination system of the TR2 building.

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Report

Abstract

The following document is a viability study of a project with different proposed solutions that have the same objective: the reduction of the energy consumption of the illumination system of the TR2 building of the UPC. The main reason is that UPC is following the general goal 2020 that is called Energy 2020, which strives to lower energy consumption intensity and carbon emissions.

The illumination system of a building consumes a high quantity of energy of the building. Firstly, to know how it works the current illumination system and how much cost the maintenance per year to the UPC. Then, propose three different alternatives to reduce the energy consumption of the TR2 building. Moreover, each of these projects is financially evaluated to ensure the return of the investment for the UPC.

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Chapter 1

1.1 Introduction

Reducing the amount of energy needed to run an illumination system has become a priority for the new types of bulbs in recent years. Because decreasing the emission of CO_2 gas has become increasingly important due to the awareness brought to environmental issues, such as climate change, which are partially caused by the presence of greenhouse gasses in our atmosphere. This happens due to the continuous increase in the demand of energy consumption

As the majority of final energy consumption is the electricity and natural gas channeled, higher final energy consumption equals to higher electricity consumption. In the developed countries the energy consumption by the buildings is between 20% to 40% of the total final energy consumption, like electricity and gas (Lombard, L. 2008). The increase of the demand for final energy consumption makes an increase of the primary energy consumption like fossil fuels, carbon and others. This makes an increase in the price of electricity. In an article from la vanguardia ("España segundo país UE donde más creció el precio de la electricidad en 2018" 21/05/2019) shows that in Spain the cost of electricity has risen 13,8% since last year.

40% of the final energy consumption of the building is from the lights (Pandharipande, A. 2015). For this reason, it is important to have an efficient illumination system of the building but without reducing the illumination conform. So it is necessary to have bulbs that are efficient with respect to the consumption of electricity.

1.2 Objective

The overarching objective of this project is to find in the building called TR2 the most effective method for the “Escuela Superior de Ingeniería Industrial, Aeroespacial y Audiovisual de Terrassa” to reduce the final energy consumption. Case studies focusing on the cost and efficiency of the optimal methods will be designed and carried out. The results will be analyzed to assist in the decision of how the university can become more environmentally friendly.

One of the central goals of this project is to find a way to reduce the CO_2 emissions that are produced by the “Universidad Politécnica de Cataluña” (UPC) which is currently using two types of lights: Halogen and Compact Fluorescent CFL. On the other hand, the CFL contains mercury, a metal that is harmful to the environment. In order to create an entirely eco-friendly system, it is required to search if there is a type of light that can reduce CO_2 emissions and do not have mercury.

1.3 Justification

This project is justified due to the UPC goal to reduce the energy consumption of all their buildings is shown in the report (“SIRENA 2017 evaluación del consumo de energía y agua”, 2018). This project is focusing on the assessment of the building TR2. The university implemented a plan called UPC Energy 2020, which has the objective of lowering energy intensity and carbon emissions by 20% for the year 2020. This plan encourages UPC campuses to be more innovative on energy consumption and to contribute towards an energy-sustainable society.

This project will focus on finding alternatives to reduce the energy consumption of the TR2 building. This will allow UPC to carry out the steps outlined in its Energy 2020 plan. The starting point within this project is to know how much are the current costs of energy consumption, as well as it is energy efficiency.

They are many ways to reduce the CO_2 emissions that are produced by the electrical energy like using another type of supply of energy as renewable energy like solar energy that is something that is already implemented in the campus in Terrassa with Gaia building. This investigation will be focused on three main alternatives: consumer behavior, structure changes of the building and technology improvement. The last one will be divided into three different methods that are going to be reviewed to find a solution for the issue of energy consumption focused on the illumination system. The first way deals with install occupancy sensors, the second is to change the light bulbs for better ones, the last one is to install the occupancy sensor with the new light bulb system.

The first alternative will be the focus on the behavior of the final consumer (students, professors, and workers) with respect to the proper use of electrical energy. The UPC made a campaign to sensitize users about the consequences of high energy consumption to try to reduce electrical energy consumption.

The alternative of the structural changes to TR2 building have the priority to reduce the electrical energy consumption by making structural changes to the building, so there is more sunlight inside the building. This way it will not be necessary to have all the lights on when is sunny outside.

It is required before to start the case of technology improvement to carry out a study of how to work the current illumination system. After, the case is going to be divided into three methods. The first method consists in realizing several calculations in the cost and how much will reduce the electrical energy consumption by installing the occupancy sensors.

The second case consists in search of the market if there are a light bulb better than CFL in terms of electrical energy consumption and does not contain mercury in their components. In the case of finding a better light bulb, a series of calculations will begin. These calculations are going to be focusing on how much will be reduced by the electrical energy consumption, the CO_2 emissions, and cost. Moreover, it will be determined if it is a profitable operation for the UPC.

The last case involves the first and the second because is a combination between them. This union requires new calculations to find out if there is any improvement in the reduction of electrical energy consumption and CO_2 emissions. Also, if the UPC could recover the investment made for this project.

1.4 Scope

This project contemplates the different alternatives to reduce the consumption of electrical energy produced by the light bulbs of the TR2 building. The plans of the building are acquired to know how the lighting system work, to know how many bulbs are and their specifications.

The project analyzes the consumption of energy within the building. After gathering all the information regarding the energy consumption of the luminaires, the next step will be to create the scenarios to know which will be better for the reduction of the energy consumption and the cost of this.

- The data will be analyzed with respect to the campaign that was made by UPC to the users regarding the good use of energy and verify if it complies with the parameters established by other campaigns.
- In the case that is possible to make structural changes to the building, the number of windows will be increased, so more sunlight can enter.
- The information obtained from the market research of the bulb and occupancy sensor will be analyzed to obtain the best equipment to reduce the electrical energy consumption.
- The information collected from all the alternatives is going to be analyzed with respect to the environmental impact. The best scenario will consider the amount of the reduction of CO_2 gas emission.
- Each alternative will consider the amount of money that must be invested to carry out each project. So the UPC does not lose money and get a return of the project.

The project will end when the best solution is found regarding the reduction of the energy consumed in the TR2 building. The changes suggested in this project would have to be carried out for the UPC if they consider these changes are worth it for them.

1.5 Planning

The research concerning energy consumption was carried out, in order to find out how the illumination systems work and to acquire the necessary knowledge to complete this study. This investigation was fundamental because it provided with all the information required. Mid-September all the planning was made as it shows in table 1. This table shows the initial and final day for each task, also their estimation, all the tasks together have approximately 750 hours of realization. They are the main tasks to complete this project as follows:

- Research: This part will provide all types of information required to realize the project.
- Methodology: This section will describe the ways of how each alternative will be realized.
- Law information: The legislation information for energy consumption and how it affects the environment. Also, how much necessary illumination has to have a building.
- Literature review: Information that supports the decision that will be considered in this project.

- Take samples: The process of taking time on the hallways of TR2 building for the case study of the sensor.
- Market research: Consisting of finding information about products related to the cases studies bulbs and sensors.
- Analysis: In the part of the results each alternative will be analyzed, this way it is possible to know which is the best option considering the electrical energy consumption, CO_2 emissions and the cost.

Table 1

Theoretical planning

Month	September				October				November				December				January				Start	Finish	Total hours
Activity	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4			
Research			■	■	■	■	■	■	■	■	■	■	■	■	■						15/09/2018	20/12/2018	250
Planning		■																			07/09/2018	07/09/2018	4
Objective					■																01/10/2018	02/10/2018	5
Scope					■																02/10/2018	03/10/2018	7
Introduction						■															04/10/2018	04/10/2018	3
Information TR building						■															05/10/2018	06/10/2018	6
Law information							■														10/10/2018	13/10/2018	15
Environment information							■														10/10/2018	14/10/2018	13
Literature review					■	■	■	■	■												01/10/2018	15/11/2018	50
Methodology case study 1						■	■	■													14/10/2018	30/10/2018	20
Visit TR2 building						■															09/10/2018	11/10/2018	10
Methodology case study 2									■	■											01/11/2018	10/11/2018	10
Methodology case study 3										■	■										10/11/2018	15/11/2018	9
Methodology case study 4											■	■									18/11/2018	20/11/2018	3
Take samples for study 2						■	■	■													09/10/2018	31/10/2018	100
Market research								■	■	■											28/10/2018	15/11/2018	70
Results from all cases												■	■	■	■						29/11/2018	18/12/2018	120
conclusions																■					25/12/2018	25/12/2018	10
Budget of my work																■					26/12/2018	26/12/2018	5
Apa norms																■					27/12/2018	29/12/2018	10
Test version																	■				02/01/2018	06/01/2018	30
Final version																		■	■		08/01/2018	15/01/2018	0
																					Total		750

There was information that was difficult to find, such as, how much lights were in the TR2 building. Which was essential to making the calculations for each of each case study.

Makes some of the activities delayed, also some changes to the document. Table 2 shows the activity which was carried out, and when. This is shown by highlighting the appropriate area of the table in light green. The areas shaded with a darker green shows where the activity was originally planned to be carried out. The test version of the study was completed a few days later, and the final version was completed during the expected time, on the 20th January 2019.

The activities such as planning, objective, scope, introduction, and information TR2 building were completed in the time expected. The others had a different time of termination, ones were finished in less time. Table 2 shows that this project took more time than expected, 808 hours were needed to complete the project. The cost of making this project is in the budget document.

Table 2

Real planning

Month	September				October				November				December				January				Start	Finish	Real total hours	Total hours planned	Difference
Activity	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4					
Research																					15/09/2018	05/01/2019	225	250	-25
Planning																					07/09/2018	07/09/2018	4	4	0
Objective																					01/10/2018	02/10/2018	5	5	0
Scope																					02/10/2018	03/10/2018	7	7	0
Introduction																					04/10/2018	04/10/2018	3	3	0
Information TR building																					05/10/2018	06/10/2018	6	6	0
Law information																					15/11/2018	04/01/2019	20	15	5
Environment information																					10/10/2018	14/10/2018	10	13	-3
Literature review																					01/10/2018	06/01/2019	70	50	20
Methodology case study 1																					01/11/2018	30/10/2018	15	20	-5
Visit TR2 building																					09/10/2018	11/10/2018	5	10	-5
Methodology case study 2																					24/11/2018	05/12/2018	8	10	-2
Methodology case study 3																					25/11/2018	06/12/2018	5	9	-4
Methodology case study 4																					06/11/2018	08/11/2018	2	3	-1
Take samples for study 2																					15/10/2018	31/10/2018	120	100	20
Market research																					28/10/2018	15/11/2018	80	70	10
Results from all cases																					02/12/2018	05/01/2019	150	120	30
conclusions																					25/12/2018	06/01/2019	6	10	-4
Budget of my work																					06/01/2019	06/01/2019	2	5	-3
Apa norms																					27/12/2018	29/12/2018	15	10	5
Test version corrections																					02/01/2018	06/01/2018	50	30	20
Final version																					08/01/2018	15/01/2018	0	0	0
																							808	750	58

Table 3
Plan for April and May

Activity	Description	Start	Finish	Time (H)	April (week)				May (week)			
New data	Search new data of the energy consumption of the TR2 building, for calculate the new theorical information to have more precision in the result. Including data for every season.	01/04/2019	03/04/2019	20								
New result	Because the introduction of the new data all the result will change. Therefore it will be done new calculations, tables, graphics and analysis.	03/04/2019	14/04/2019	100								
Conclusion	With the new information will be necessary to change the conclusion of the thesis.	15/04/2019	15/04/2019	8								
Introduction	Improve the introduction including new information	16/04/2019	17/04/2019	10								
Justification	Put the information of environment in this section	18/04/2019	20/04/2019	12								
Methodology	Making this section more representative	21/04/2019	22/04/2019	10								
Corrections	Make all the correction suggested by the tutor, like putting the structure requirements of the building, quantity of lux per space, specify why there are only 3 cases studies and why others options was not including in this work.	23/04/2019	30/04/2019	60								
				220								

Considering that the past data information was not representative for calculating the electrical consumption of the lights, because only considered one week of the year. Therefore, it was necessary to research more information and take the amount of data that can be representative of the study. The past table shows the planification for the restructuring of this study. The new data will consider the 52 weeks of the year to know the behavior of the energy consumption of the lights in all the year. After, all the calculations were made again, making the result changes a lot.

Chapter 2

2.1 General Information of UPC

The project will be carried out in the "La escuela superior de ingenierías industrial, aeroespacial y audiovisual de Terrassa" ESEIAAT. This is a public center of high education and investigation of the UPC. The following figure shows how the campus ESEIAAT is distributed.

Figure 1 Campus of ESEIAAT in Terrassa (ESEIAAT; https://eseiaat.upc.edu/es/escuela/on-som)

2.1.2 Information of TR2 building

The campus is located in Terrassa and inside the campus is the TR2 building as it shows in figure 1. The TR2 building is located behind the TR1 and TR3, all three buildings are connected but they have different consumption of electricity. The next figure shows the general information of the building TR123.

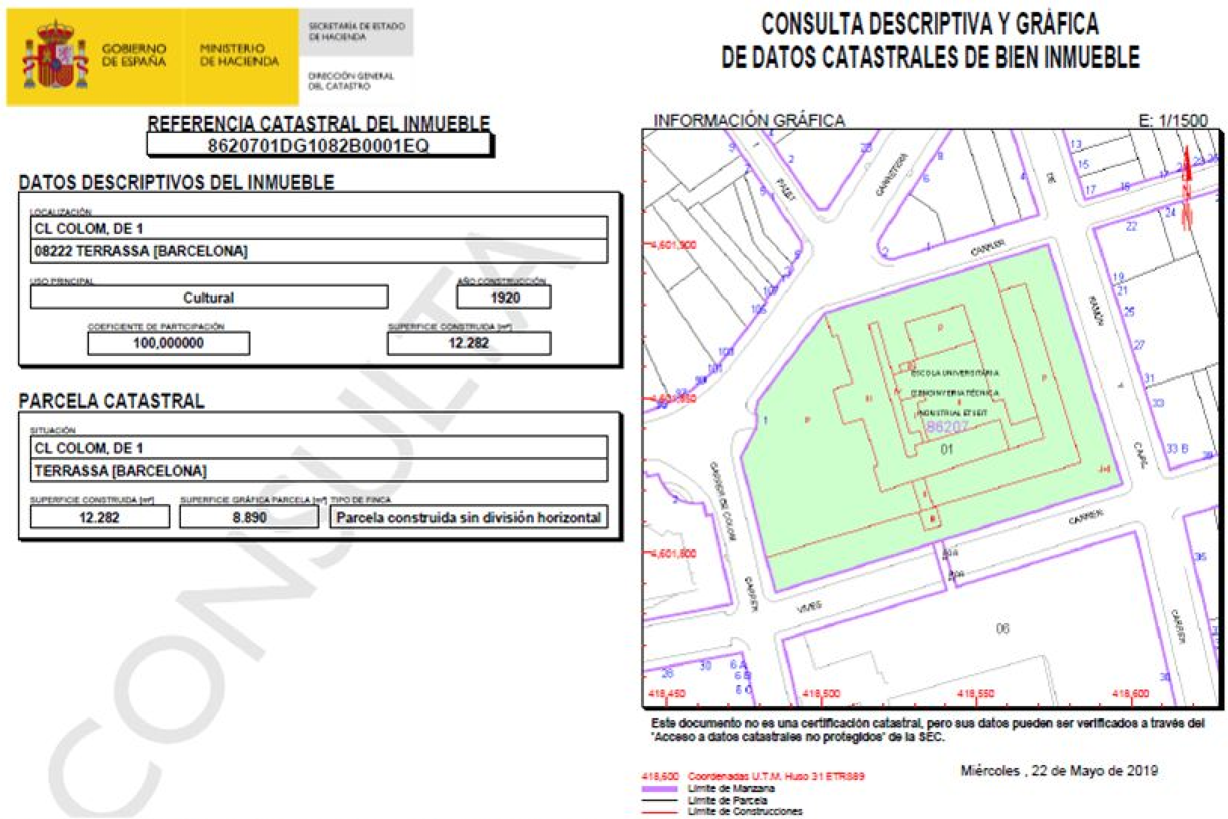

Figure 2 TR123 Building "Gobierno de España"(22/05/2019) https://www.sedecatastro.gob.es/

In addition in the annexes, there are building plans for each floor. Now it is possible to know how the building is structure inside. For example how many classrooms, offices, meeting rooms they are. Also, these plans specify the quantity and the type of light are in every part of the building TR2.

2.2 Europe Union legislation

The European energy efficiency directive 2010/31/EU has as objective to promote the energy efficiency of buildings in the European Union, considering the external climatic conditions and local particularities, as well as the internal environment requirements and the profitability in terms of cost-effectiveness. They established that the member states must ensure that an energy performance certificate is issued for buildings that sold or rented to a new tenant, and for buildings in the that a public authority occupies a total useful area of more than 250 m2 and that they are usually frequented by the public.

The certificate of energy efficiency in buildings provides owners and potential tenants with an objective tool to assess the energy consumption of the place where they will carry out an economic activity, or where they will live. The member of each state has to develop a methodology of energy efficiency certificate considering this minimum requirement in energy efficiency in the facilities.

- Illumination.
- Production of domestic hot water (DHW).
- Heating.
- Refrigeration.
- Ventilation.

This directive has a very important consequence which is that the starting of December 31 of 2020, all new buildings constructed must be of almost zero energy consumption, being mandatory for public buildings as of December 31, 2018.

The Directive 2012/27/EU on energy efficiency establishes a common framework of measures for the promotion of energy efficiency within the European Union to ensure the main objective of energy efficiency of 20% savings by 2020. The directive establishes minimum measures that each member state will develop according to it is own circumstances and laws. In 2016 the commission also proposed an update to the energy efficiency directive that includes making 30% of energy savings for 2030.

2.2.1 Legislation of Cataluña

Cataluña is governed by the Generalitat of Cataluña because they are an autonomous community, which means that they have political and financial autonomy. They can create new laws without breaking any Spanish law. Furthermore, they have:

- Financial control.
- Management of the autonomous government.
- Election of the government.
- The President of the executive.
- Participation in the reforms of the Constitution.
- Control of the constitutionality of laws and provisions with force of law.
- Participation in the composition of the Senate.

In the case of energy consumption Cataluña follows the European directives on energy efficiency 2012/27/EU of the European Parliament and of the Council, of 25th October 2012. The law establishes that all buildings (existing or new buildings) must have a certificate of energy efficiency. In Cataluña, from 1st November 2007, new buildings have to have an energy certificate, and from 1st June 2013, it is also mandatory for existing buildings and homes to reduce energy consumption by 20% in 2020.

2.2.2 UPC Application

These regulations caused the UPC the need to control the quantity of energy sources that are spent every day because if the UPC does not reduce 20% their energy consumption they can suffer penalties for breach this legislation, they have until 2020 for make this reduction of energy consumption. One of the main final energy consumption is in the illumination, making it necessary to reduce the electricity consumption of these lights but without breaking other laws like the minimum quantity of light that is required for different spaces.The UPC follows the directive 2012/27/EU for energetic efficiency.

Chapter 3

3.1 Literature Review

Nowadays the energy consumption has been increasing with the passage of time due to the fact that the population is also growing and between them exist a positive correlation (Wang, Q. 2014) and this causes damage to the environment. This study reveals that environmental aspects and quality of life indicate that environmental pollution is largely linked to the increasing use of energy (Akella, A. 2008). This is why it is important to reduce energy consumption or to make changes in the energy system of a building to use renewable energy such as solar energy with solar panels.

The United Nations wants to increase the utilization of renewable energy to reduce environmental pollution. However, in 2013 was estimated that the 19,1% of the global final energy consumption was sourced from renewables (Bhattacharya, M. 2015). This means that there is still a big gap to become the main source of energy used.

Therefore, it is important to reduce the final energy consumption because the main source of this energy produces higher CO_2 emissions. A study reveals in 2013 that buildings account for about 40% of the global energy consumption and contribute over 30% of the CO_2 gas emissions (Yang, L. 2013). A large proportion of this energy is used for thermal comfort in buildings. However, the lights of a building are almost 40% of the total final energy consumption

(Pandharipande, A. 2015), making it important to have an efficient lighting system that keeps an illumination conform.

Currently, the light bulbs most used are the CFL because they are cheap and consume less energy than others. The article (Mills, B. 2014) presents how the CFL and LED require about 80% and 85% less electricity, compared to the incandescent lamps, and their life cycle is 6 and 26 times longer, respectively. What implies less greenhouse gas emissions. Also, this paper (Seong, R. 2013) studied the potential environmental impacts from these three types of lights, discovering that incandescent lights have more impact on the environment because their life cycle is short and the amount of energy they consume.

Following this, the CFL, with a great life cycle and less energy consumption, is good but contains Mercury. However, CFL is still a better option than incandescent lights, but the lifespan of LED is longer and has the best energy efficiency of all the lights of the current market, making it friendly to the environment.

This investigation has proved the existence of several articles and researches related to the study of the LED luminaires and how efficient they are on different levels of energy consumption. An example in the article (Morgan, P 2017), is made a comparison between the luminous efficacies and life cycle of the top-performing LED and conventional lighting products; showing that LED had the best performance than conventional lighting products in every category. Their life cycles were also higher, giving them a lower life cost to the ownership compared to conventional lighting products.

In terms of economy, the LED lights seem, in the beginning, the most expensive option but, in the long term, they become the most economical choice and this happens because of the fact that the life cycle is bigger than the other options. With one bulb, it is possible to produce the work of 5 CFL bulbs and 50 incandescent bulbs. They consume less Watts, also, making them the cheaper option for the customers. In the article (Mills, B. 2014) they build an economic model that shows how energy efficient is the LED lights and how these types of lights are relatively inexpensive compared to the white appliance and other common residential energy efficient technologies.

There is another way to reduce the energy consumption of the lights, which is to use occupancy sensors that will control the lights, turning on when they detect some movement and turning off after 10 seconds of no motion detection. Researches in the past have shown that the use of occupancy sensors for control of lighting can save around to 30% of electrical energy used for lighting (Garg, V. 1999).

The combination of LED lights with occupancy sensors will be the best option for reducing dramatically the energy consumption of a building. This can be expensive in the beginning, but over time, it is possible to save a lot of energy making this option profitable. Moreover, this will greatly reduce the CO_2 emissions produced by the building.

Chapter 4

4.1 Methodology

First of all, it is required to know all the alternatives that are possible to implement to reduce the energy consumption of the building TR2. In this project is going to manage three different options. The first option is to check if the campaign that is doing the UPC with the consumer behavior is working. This consists to promote the users (students, professors, and workers) to turn the lights off if they are leaving the place. Also, do not leave any equipment on after being used. This is going to be checked with the records of the energy consumption of the building in the past years and then comparing if the reduction is according to studies of this topic.

The second alternative is to make structural changes to the building. Such as creating new windows that allow sunlight enter in the building making a reduction in the energy consumption because it would not be necessary to turn on all the lights of the building in the morning and afternoon. Other structure changes can be to reorder the lights of the building to have more lux efficient and they cover all the places with fewer lights. Before making any changes of the structure it is necessary to research if the building is historic because there is a law the protect them of any structural change.

The last option is to make a technology improvement in the current illumination system. To do so, in the beginning, there will be research made for all the current lights that are in the market and is going to be selected the one who has the most reduction in the energy consumption and CO_2 emissions, prioritizing the cost benefit for the UPC. Additionally, occupancy sensor will be sought to control the lights of the hallways, for the only turn on when are people there.

This project will be developed using the platform SIRENA of the "Universidad Politécnica de Cataluña" to calculate the electrical energy consumption of the lights from the TR2 building. This is a platform that is used as an informatics tool online, for measuring all the information related to the consumption of resources (electricity, water, and gas) within the university building. From this, it automatically generates comparisons, graphs, consumption indicators, and associated environmental impacts. This project is only going to focus on electricity.

An issue with SIRENA is that it does not give us specific information of the electrical energy consumption; it only shows the quantity of energy spent each day, month or year. It does not, however, tell us which appliances use this energy. Therefore, it is necessary to calculate how many lights there are in the building, which type of bulb they are, and how many hours in the day they are on. Once the information is gathered, the amount of energy that the lights are using per day can be calculated, and a correlation can be made with the information that SIRENA has given us.

In this project, there are two variables to analyze, one being the theoretical energy consumption of the lights that are in the TR2 building, that it is called TCL. It will be calculated knowing all the quantity of lights are and their schedule of use. The lights situated in the hallways are always switched on between 7 am to 10 pm every day from Monday to Friday. It will be using the schedule of the classroom that is in this building and quantifies the hours that are used and the quantity of lights in that classroom. For this project, the schedule of the meeting room and the professor's offices will be 8 hours of use per day, as this is the average amount of time these rooms are occupied by a professor in the UPC.

After obtaining this information, SIRENA will be used to calculate the energy consumption of every week of the year 2018, to have the real, final energy consumption in general called REC. In our case, the independent variable is the theoretical consumption of the lights, as it does not matter how much change the real energy consumption. It will not affect TCL, however, REC will be affected by TCL because when the lights consume energy this will affect the value of the variable REC.

The hypothesis is: The energy consumed by the lights will directly affect the total final energy consumption of the building TR2. The independent variable is TLC and the REC is the dependent variable. After continuing, it is necessary to prove which of these two hypotheses is correct.

H_0= The two variables in this study are independent.

H_a= The two variables in this study are related.

If H_0 is proven to be correct, the next step will be to search for another way to calculate the energy consumed by the lights of the TR2 building. But, if this it is not the case, the study will continue. In this scenario, an equation must be created to calculate the real energy consumption of the lights.

It is required to use a dispersion diagram that will contain the variables X= TCL and Y=REC. There will be 52 values from each variable that is the energy consumption of every week from the year 2018. The theoretical values of the energy consumption by the lights in some weeks are different because there are holidays or events, meaning UPC is closed, reducing the energy consumption of the lights. With this, there is a representative behavior of real and theoretical energy consumption. Using these values a dispersion diagram will be made which will help to identify if there is a tendency or not.

Positive correlation Null correlation Negative correlation

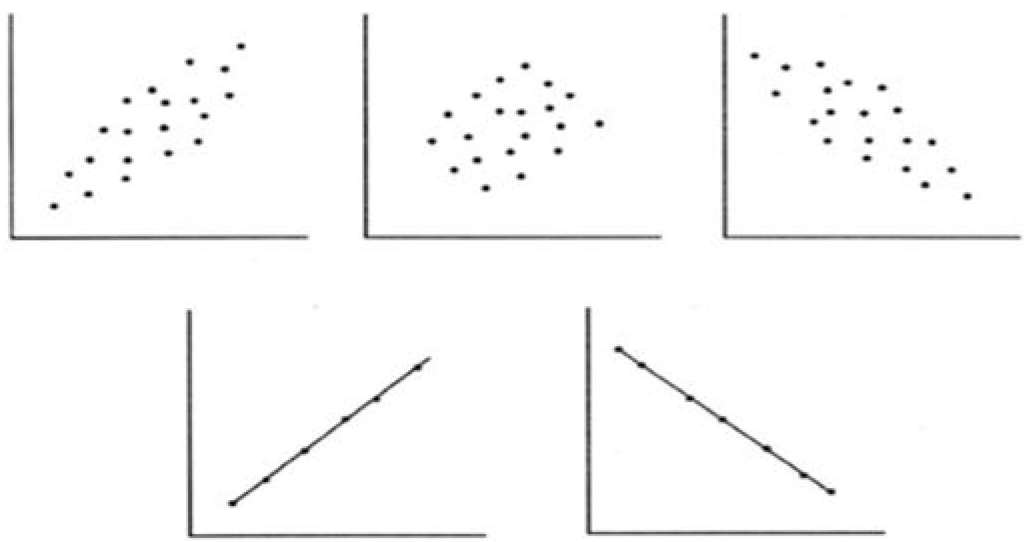

Figure 3 Correlation

Positive ideal correlation Negative ideal correlation

For our case study, it is likely that only one of the three first graphics of figure 3 will appear. The most important is that the result is not the graphic of null correlation because that will mean that the H_0 is true and is required the opposite.

In order to confirm this result, the covariance must be calculated:

$$Sxy = \frac{\sum(Xi - Xm)(Y\,i - Y\,m)}{n-1}$$

Xi = Variables of TLC.

Xm = Mean of TLC.

Yi = Variable of REC.

Ym = Mean of REC.

n = Number of individuals that has the sample.

There are some problems with the covariance, such as the units, so to prevent such things that affect the case, it is better to work with the correction of the covariance that is called the Pearson correlation coefficient:

$$r = \frac{Sxy}{SxSy}$$

Sx = Standard deviation TLC.

Sy = Standard deviation REC.

$r < 0$ Reverse linear relationship.

$r > 0$ Direct linear relationship.

r = Independent variables.

For the case study, it is required that the Pearson correlation coefficient to be near to 1 or -1 because this means that there is a relationship between the variables. If this is the case, a simple linear regression can be made to find the equation needed to calculate the real energy consumption of the lights from January to December of 2018. This is the data that will be used for the case of technology change.

4.1.1 Old illumination

The first study will allow us to analyze how much energy is being consumed by the lights. Also, to see how long their lifespan is for each light knowing that they can operate 10.000 hours and the time they operate every day. Moreover, how expensive is the maintenance during their lifespan. It is important to investigate all of these areas because of the maintenance cost, to know if it is more efficient for the university to wait until the lifespan of their current lights to end before changing them. Comparing this factor with information from the other studies will also provide a useful point of comparison.

For this, there are three plans of the TR2 building from the maintenance department, that show how many lights are on each floor, the type of light used and how many watts they consume per hour. Therefore, it is necessary to count how many lights are per floor, group them by type of light and how many watts they consume. After this, it is possible to calculate the theoretical energy consumption of the lights with the schedule of the classrooms, the hallways schedule that is from 7 am to 10 pm and the regular schedule of the professor offices from 9 am to 6 pm.

Moreover, with this information, it will be possible to calculate the cost of the energy consumption of the lights and how much of this cost is reflected in the general cost of the electricity of the TR2 building.

4.1.2 Lights automatization

The lights currently turn on and off by the concierge. Between 7 am to 10 pm that is when approximately the switch will turn on. So, in order to reduce the consumption of the energy, it is to implement occupancy sensors into the lights, meaning they will only turn on when they detect the movement of people. When this has been carried out, it is certain there will be a reduction in the consumption of the energy used by the lights. However, it is not certain that the cost will also be reduced because it could be possible that the implementation of the sensor will be expensive and the return of this investment would take some years.

4.1.2.1 Process of taking samples

For this case study, it is required to take some samples in order to know, with a sensor implemented, how much time the lights are switched on and how much time they are off. So, the process of taking the samples is going to Terrassa campus and go inside the TR2 building and dividing every floor into two sections right and left. There are 30 samples to take, meaning they are 10 per floor and 5 per section, every sample is 1 hour.

The process consists of sitting in the hallway with a chronometer starting to run whenever someone passes through the hallway, the chronometer will stop once they have left. It is also necessary to count how many times this happens because after the person leaves the lights of the hallway will stay on for approximately 10 seconds and turn off until another person arrives. Then, every sample will have the time that people spend in the hallway and how many times this happens, so these two values can be used to have the total time where the lights will be on with a sensor.

4.1.3 New illuminations

In this study, it is necessary to research the different types of lights and how much energy they consume, the expense of their maintenance and the length of their lifespan. After this, it is necessary to look at how much the installation of the new lights will cost and how much time it will take for the university to have a benefit from the investment.

After making the research of the lights and knowing which is the best option for our study, it is going to be taken as the most efficient type of light in the world. Once known how many lights there are from the previous study and their specifications like the longitude to know what exactly lights is required to buy and calculate all the cost of these lights with the cost of change all them. It will be around one hour of work of a technique from the maintenance department for each light replace. Then sum all of the costs to calculate the net present value and the internal rate of return for observing if the project is rentable to the UPC and to know how much time they will recover the investment.

4.1.4 Net present value and internal rate of return

The net present value is the difference between the present value of cash inflows and the present value of cash outflows over a period of time. It is necessary to calculate because it will be helpful to analyze the profitability of investment in the project. It is important to highlight the net present value and the internal rate of return will be calculated for cases 2, 3 and 4. Because is important for the UPC to know which option in economic terms is the best, the cash inflows will be calculated as saving cost that generates the project and the cash outflows will be the investment required for executing the project,

The net present value is the value in the present of a sum of money, in contrast to some future value that will have when it has been invested at compound interest. So, in our case, it will be the investment required to make each case study and the money that UPC will win are the savings cost of energy consumption.

$$NPV = \left(-Investment + \frac{Savings}{(1+r)^1} + \frac{Savings}{(1+r)^2} + \frac{Savings}{(1+r)^n}\right)$$

r = Discount rate, 10% is the rate which will be used for this project, as it is a low-interest rate, so it will not put at risk the accuracy of the project's outcomes. Also, with the passing of time, the money will have less value because of inflation.

n = Number of time periods, a 5 year period will be used for the sensors because this is the average lifespan for this type of product and 20 years for the LED lights because the lifespan of this type of lights is around 20 years.

Project with NPV > 0 increase the benefits of UPC

Project with NPV < 0 decrease the benefits of UPC

Internal rate of return is a discount rate that makes the net present value zero. Meaning that the cash flows of the project are equal to the project costs. It is important to calculate it because the indicator will decide which project will be the best option for UPC to implement. There is no formula to calculate the IRR because the way to calculated is making the VPN zero with a specific discount rate (r).

If the IRR > discount rate (10%), accept the project.

If the IRR < discount rate (10%), reject the project.

4.1.5 New illumination and automatization

For the last case study, the information will be taken from the previous cases 2 and 3 and putting together the two options, meaning the occupancy sensor with the lights to have the mayor reduction of energy consumption. After putting all this data together, it will be calculated. The VPN and the IRR to check if is a better option than the other two case studies.

Chapter 5

5.1 Results

5.1.1 Consumer behavior

The UPC has been making a campaign for the last years to make aware to the user of the energy consumption and how this affects the environment. Consists of creating events for the students and tell them about this issue, make promotions in social media and by the ESEIAAT web page. Put information inside the campus about this topic for the users can read it and help by reducing the energy consumption.

The UPC began creating their Plan 2020 in 2007. Its main objective is to reduce energy consumption by 20% throughout all their campuses. As shown in the chart, the UPC is far from completing this goal, as the last collection of data from SIRENA shows that there is just a 4% decrease in energy consumption between the years 2007 and 2017. This is primarily due to the construction of the new campus “diagonal besos” in 2016, and other new buildings.

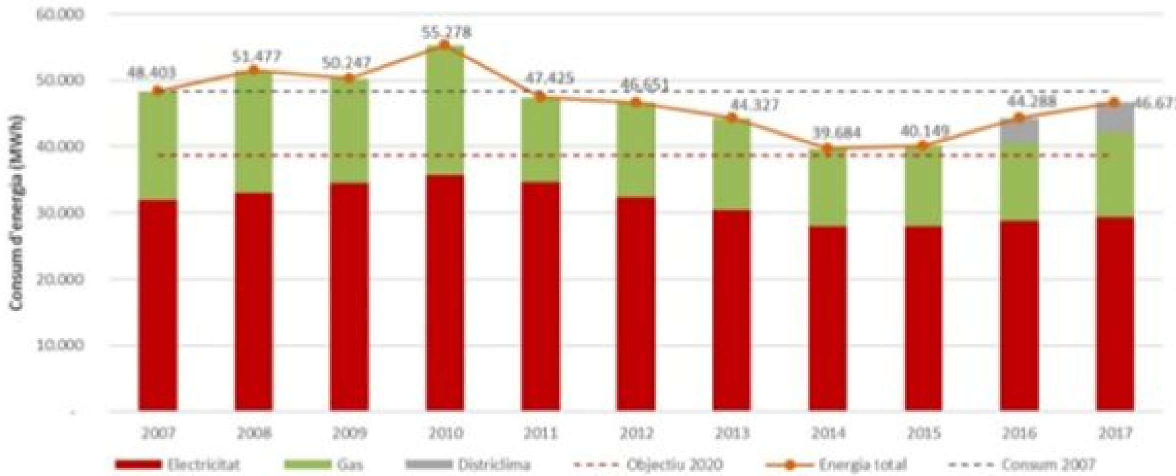

Figure 4 UPC Energy consumption SIRENA report 2017

Before the introduction of this new campus, the goal was almost reached as their plan was supported by a campaign that encouraged those on campus to be more aware of their habits which affect energy use, such as turning off unused lights. UPC also implemented the use of green energy, such as the Gaia building, which ran mainly on photovoltaic energy, as a way to reach the goal of Plan 2020. This project focuses on the TR2 building, so it will be from this building alone that data will be collected. SIRENA only has data from this building since 2010, which is why the data collection chart starts in that year.

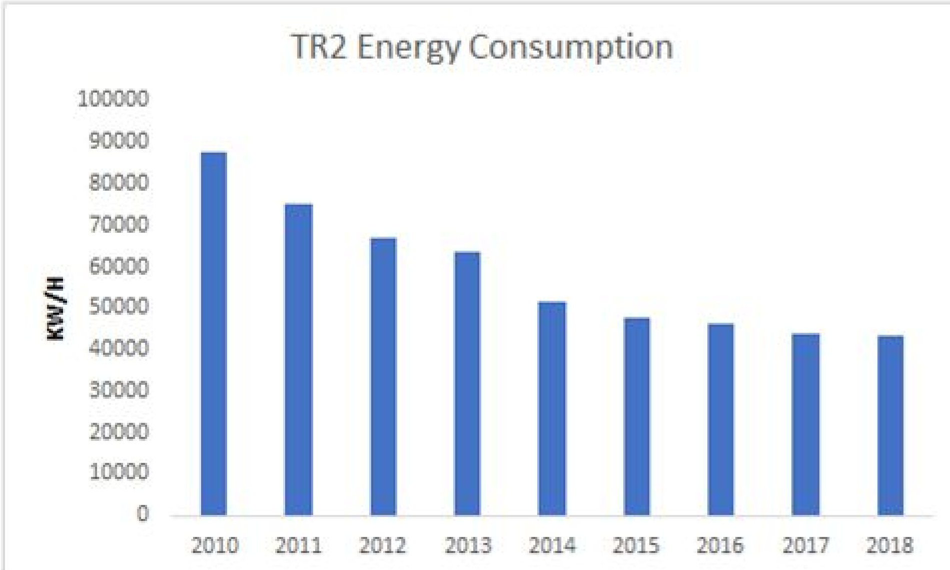

Figure 5 UPC TR2 Energy consumption 2010-2018

The graphic shows that there is a huge reduction in energy consumption. This building already reached its goal of Plan 2020 and continued in its energy reduction. Despite this, the UPC is far from reducing its energy sufficiently across all of its buildings. There is a possibility that there is still a way to improve this reduction to help the UPC to reach its goal. For this reason, it is important to consider the factors which affect the energy usage of the building and how these can be altered to use less energy.

The mean of the percentage of reduction is 8% meaning that the campaign designed in Terrassa was successful, as in (Delmas, MA 2013) exposes, after conducting a study of 525,479 subjects from 1975 to 2012, they quantify the energy savings from information strategies on average was 7,4%. But it is important to highlight that in the last year the reduction of energy consumption was very low. From 2017 to 2018 energy consumption was reduced by just 1%. The campaign of the UPC worked, but it has reached the limit of what it can reduce, creating the need to check other ways to reduce the energy consumption of the TR2 building, such as changing the structure of the building or the technology used.

5.1.2 Structure modification

After making the respective researches, it was found that the TR2 building was built in 1920 and is a Catalan modernist building. The TR2 is almost one hundred years old, and has a history of involvement with the textile industry of Terrassa, covering the needs of this industry which was important for the early 20th century.

Looking to the law 9/1993 of September 30th of the Catalan Cultural Heritage, this building is a part of the history of Cataluña for which is protected by this law. The building has to be conserved and structural changes that can affect the integrity of the cultural value of the building cannot be made. For this reason, it is not possible to conduct any study to make a structural change that could benefit the reduction of the building's energy consumption.

5.1.3 Technology improvement

In the current market of lights bulbs, there are four alternatives to buy like incandescent, halogen, CFL and LED. The TR2 building is currently using the CFL bulbs and it is necessary to check the specifications of these types of bulbs to decide which will be the best option for the UPC. The next table shows all the properties that these bulbs have. The UPC want to reduce the energy consumption of the lights but without making an investment that generates losses. The core values will be in the cost, the reduction of CO_2 emissions and energy consumption.

Table 4.
Lights specifications

Bulbs	Incandescent	Halogen	Fluorescent	LED
Lifespan (hours)	1000	2500	10000	50000
Cost	1,00 €	1,54 €	2,48 €	9,00 €
Cost per hour	0,00100 €	0,00062 €	0,00025 €	0,00018 €
Quantity of bulbs for 50000 hours	50	20	5	1
Total Cost	50,00 €	30,80 €	12,40 €	9,00 €
Efficient vs incandescent	0%	30%	77%	85%
Have mercury	No	No	Yes	No
CO2 Emissions 50000 Hours	1155 Kg	809 Kg	270 Kg	173 Kg

There is one bulb that has better properties than the others and it is the LED bulb. They have the longest lifespan, making this bulb the cheapest option in the long term. LED bulbs also are the most energy efficient compared to a normal incandescent bulb of 60 watts. They do not use mercury, which is the most significant drawback when using CFL, because this metal is harmful to the environment and human health. The last part of the table shows that also LED bulbs produce less CO_2 emissions. Due to these findings, it was decided to make the calculations of the technology improvement with LED bulb lights.

5.1.3.1 Old illumination

The first step was to count all the lights that are in each plane, during which time the distribution of various working spaces within the building was also noted. It was decided, therefore, to create 3 categories: offices, classrooms and the hallways. Then, the number of lights found within each category was recorded, and cross-referenced by floor and type of consumption of the light, as it shows in table 5, 6 and 7.

Table 5
Lights floor 0

Floor 0	Fluorescent 58W	Fluorescent 36W	Fluorescent 18W	Fluorescent 14W
Offices	56	76	22	0
Classrooms	0	12	0	114
Hallways	19	1	1	0
Total	75	89	23	114

Table 6
Lights floor 1

Floor 1	Fluorescent 58W	Fluorescent 36W	Fluorescent 26W	Fluorescent 18W
Offices	128	3	0	4
Classrooms	0	0	0	0
Hallways	0	0	39	0
Total	128	3	39	4

Table 7
Lights floor 2

Floor 2	Fluorescent 58W	Fluorescent 36W	Fluorescent 26W	Fluorescent 18W
Offices	385	12	0	7
Classrooms	40	0	0	0
Hallways	4	73	0	0
Total	429	85	0	7

After collecting this information, it was decided to group all of the findings together, in order to have the general information of the TR2 building in one place, as is shown in table 8. Now, it is clear how many lights are by category and in total. It is also possible to see which types of lights there are. There were five different types: fluorescent 58W, fluorescent 36W, fluorescent 26W, fluorescent 18W, and fluorescent 14W.

Table 8
Lights TR2

TR2	Fluorescent 58W	Fluorescent 36W	Fluorescent 26W	Fluorescent 18W	Fluorescent 14W
Offices	569	91	0	33	0
Classrooms	40	12	0	0	114
Hallways	23	74	39	1	0
Total	632	177	39	34	114

With this information, it is possible to calculate the energy consumption per day for each category because it is know how much time the lights are on in each category. The first category, offices, the lights are on an average of 8 hours, because this is the time that a professor usually stays. In the second category, the classrooms, the average is 3,4 hours. It was calculated through the schedule of each classroom in the current semester.

$$Classroom\ Averague\ time = \frac{\frac{Total\ lessons\ \ time\ in\ a\ week}{Number\ of\ classrooms}}{Days\ of\ a\ week}$$

$$Classroom\ time = \frac{187/11}{5} = 3{,}4\ hours/day$$

Table 9
Energy consumption TR2

Place	Energy consumption (kWh)	Average time use per day	Energy consumption(kW/day)	Energy consumption(kW/year)
Offices	36,872	8	294,976	64010
Classrooms	4,348	3,4	15	2868
Hallways	5,03	16	80,48	19154

Table 9 shows the category that consumes more energy are the offices and this is because offices contain the majority of lights within the TR2 building with 693 lights in total, almost 70% of the lights, but consuming 80% of the total energy consumption of the lights. This happens because the offices contain the major quantity of fluorescent 58W which are the lights that use the most energy.

The information regarding the energy consumption of the year was calculated using the days that the UPC was open. These days were found using the UPC web page and looking at their academic calendar year. There are 62 days of holiday for students, while the professors continue to work for a longer period, specifically in the month of July. There are 65 days in which the university is closed because they were Sundays or holidays. This gave a total of 127 days that the UPC is closed and 238 that it is open, so this means that 238 days of the year the UPC will use the lights of the classrooms and office. This also excludes the 44 Saturdays of the year because the professors do not come on Saturday and there is also no class on Saturdays.

Table 10
Time UPC is working

Fluorescent life cycle	Time of UPC closed	Time of UPC open	Time of UPC open (excluding Saturdays)	Professor works on July
10000	127	238	194	217

Now having all this information, it is known that the lifespan of these types of lights is 10000 hours, so it was decided to calculate how many years are the life cycles of the lights per category. Knowing the average time use per day was possible by multiplying this value with the time the UPC is open, then was took the value of 10000 hours and divided by the time use of the lights per year. The result is shown in Table 11.

Table 11
Information actual illumination

Place	Number of lights	Average time use per day	Time use lights per year (hours)	Life cycle (years)	Maintenance time in 15 years per light	Total maintenance time in 15 years
Offices	693	8	1736	5,76	2,60	1805
Classrooms	166	3,4	660	15,16	0,99	164
Hallways	137	16	3808	2,63	5,71	783

The maintenance department has been using this type of fluorescent lights for 15 years, and in this period they replaced 2751 lights because their lifespan had expired. This information is important because it will be necessary to calculate the cost of the maintenance of this type of light.

Before calculating the actual cost, it is necessary to calculate the real energy consumption because now, there is only the theoretical energy consumption and in order to have a better approximation of the cost, it is required to calculate the real energy consumption. This data will be taken from SIRENA. It was decided to do it by the weeks of the year 2018.

It was taken every week of the year with the help of SIRENA that gave us the real energy consumption per week, which was in total 52 weeks. This gave us a representative behavior of the energy consumption of the TR2, next is the graphic that shows the behavior of the energy consumption.

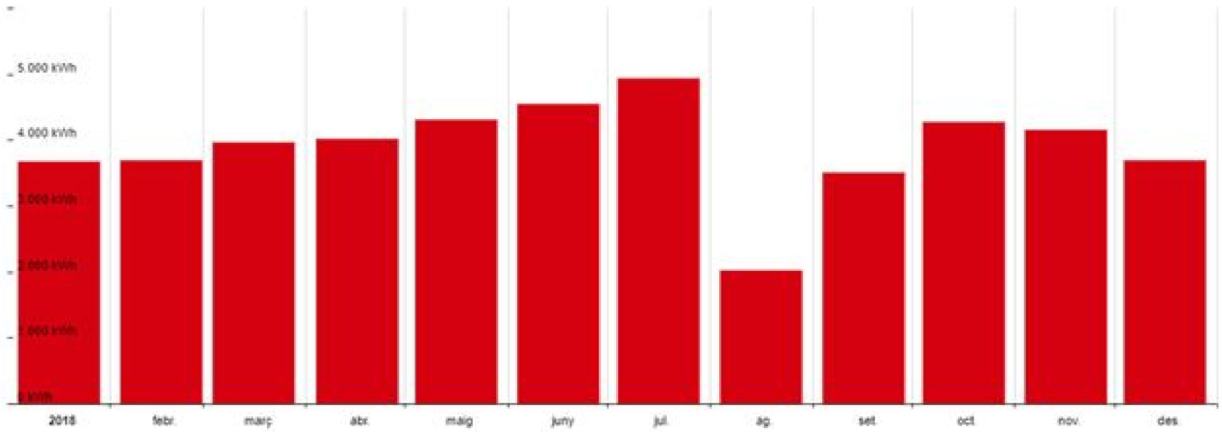

Figure 6 UPC TR2 Energy consumptiom 2018 by SIRENA

As it looks in the figure 6 the major activity of the energy consumption is in between sprint and summer, this is because there is a more academic activity like lessons and professors working in their office in the building. Also, in June and July are the months with the highest energy consumption and this is because the heat was very high that they had to turn on the air conditioner. On the other hand, August is the month with less energy consumption because is vacations and the UPC is closed in that period of time.

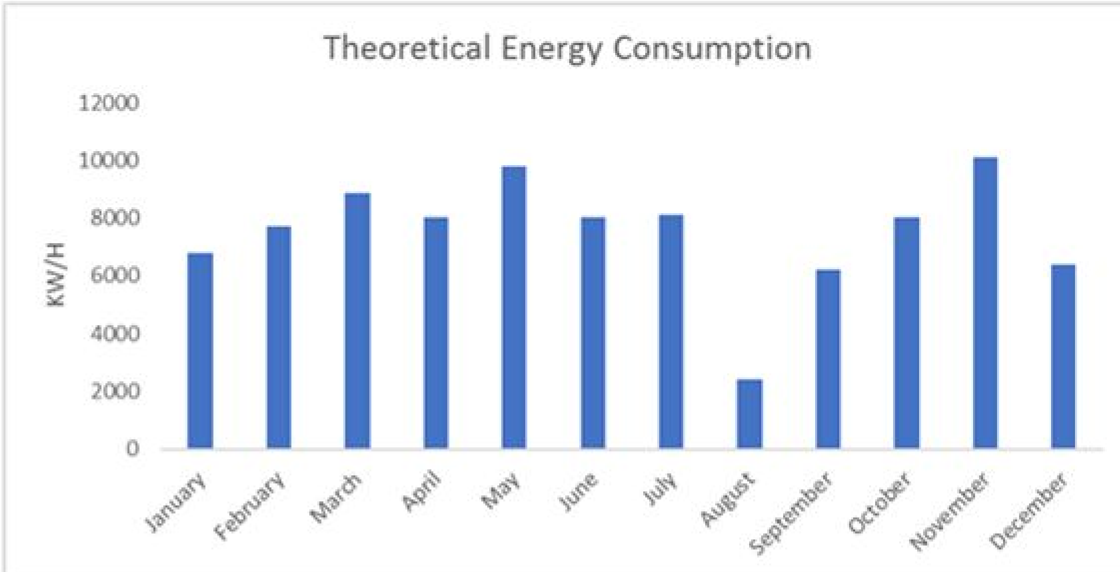

Figure 7 UPC TR2 Theoretical energy consumptiom 2018

As it shows in figure 7, the theoretical consumption is different, because the real is much lower than the theoretical. This is because the theoretical consumption assumes that when the lights are on, they are all on but the truth is that they are not on all together because the university wants to consume as little as possible making that there is not sufficient lux in the hallways, offices, and classrooms. This is something that the university has to change because is against the legislation of Spain, as it is shown in the annexes.

With this data, it is not possible to calculate the real energy consumption of the lights because is required more quantity of data. There are some months that do not show the same behavior than the theoretical data. The next step was to take the data by the week of the year, there are in total 52 weeks in the year making a good quantity of data for the study.

Table 12.
Theoretical and real energy consumption by weeks of the year 2018

Year	Week	Real Energy	Theoretical energy	Year	Week	Real Energy	Theoretical energy
2018	01	583,34	477,85	2018	27	1.151,68	2033
2018	02	911,70	2101	2018	28	1.217,31	2033
2018	03	944,14	2101	2018	29	1.144,69	2033
2018	04	830,17	2101	2018	30	1.024,99	2033
2018	05	799,24	1430	2018	31	689,45	477,85
2018	06	941,82	2101	2018	32	500,33	477,85
2018	07	895,11	2101	2018	33	330,47	477,85
2018	08	989,78	2101	2018	34	388,51	477,85
2018	09	963,93	2101	2018	35	482,62	477,85
2018	10	1.056,86	2101	2018	36	722,33	545,85
2018	11	1.015,62	2101	2018	37	754,23	1484
2018	12	1.027,12	2101	2018	38	922,74	2101
2018	13	456,10	477,85	2018	39	1.039,76	2101
2018	14	882,66	1712	2018	40	956,95	2101
2018	15	957,66	2101	2018	41	872,39	1722
2018	16	874,55	2101	2018	42	957,64	2101
2018	17	1.079,20	2101	2018	43	971,34	2101
2018	18	908,35	2101	2018	44	813,62	1710
2018	19	889,43	1713	2018	45	892,87	2101
2018	20	947,23	1755	2018	46	1.005,34	2101
2018	21	981,03	2101	2018	47	1.070,93	2101
2018	22	1.068,99	2101	2018	48	1.014,75	2101
2018	23	1.017,85	2101	2018	49	915,08	1710
2018	24	875,64	1722	2018	50	1.057,83	2101
2018	25	1.186,05	2101	2018	51	1.031,55	2101
2018	26	1.272,09	2101	2018	52	485,96	477,85

For the theoretical energy consumption was necessary to calculate it in three different steps. First was the calculation of the office that is 8 hours around the day. After was necessary to calculate all the energy consumption of the classrooms that have classes every day and finally the energy consumption of the lights from the hallway. Then the result will be the summation of these three steps, as presented in table 12. These calculations include the days when the UPC is close, holidays, Saturdays, Sundays, and professors working in July.

Then it is possible to notice that they are some weeks of the real energy consumption that do not follow the same behavior than the theoretical energy consumption. Also, there are other weeks that have similar values than others making repetitive data. This data can affect the calculations of the study. For this reason, that data was removed, then was considered the data with the same behavior between the two variables and that variability, as it is shown in table 13.

Table 13.
Used data

Year	Week	Real energy consumption (kWh)	Theoretical (kWh)
2018	01	583,34	625
2018	05	799,24	1430
2018	10	1.056,86	2101
2018	13	456,10	477,85
2018	14	882,66	1712
2018	17	1.079,20	2101
2018	19	889,43	1713
2018	20	947,23	1755
2018	22	1.068,99	2101
2018	24	875,64	1722
2018	25	1.186,05	2101
2018	26	1.272,09	2101
2018	27	1.151,68	2033
2018	28	1.217,31	2033
2018	33	330,47	477,85
2018	34	388,51	477,85
2018	35	482,62	477,85
2018	36	722,33	1177
2018	37	754,23	1484
2018	41	872,39	1722
2018	44	813,62	1710
2018	47	1.070,93	2101
2018	49	915,08	1710
2018	50	1.057,83	2101
2018	51	1.031,55	2101
2018	52	485,96	477,85

At shows, in figures 8 and 9 the behavior looks really similar. Then is possible to make a correlation between the real energy consumption of the lights and the theoretical energy consumption of lights.

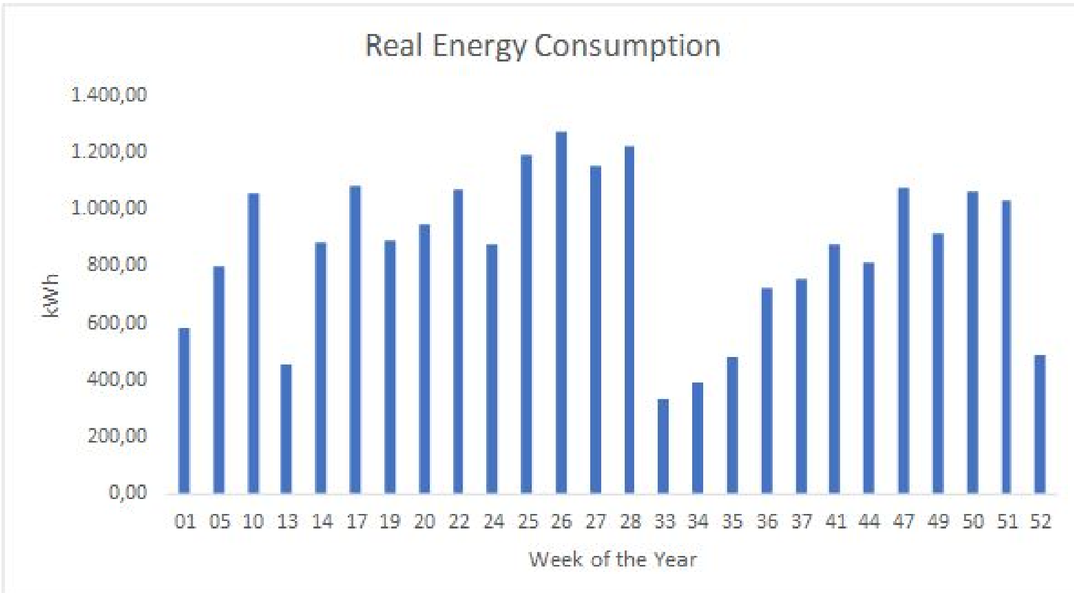

Figure 8 UPC TR2 Real energy consumption (used data)

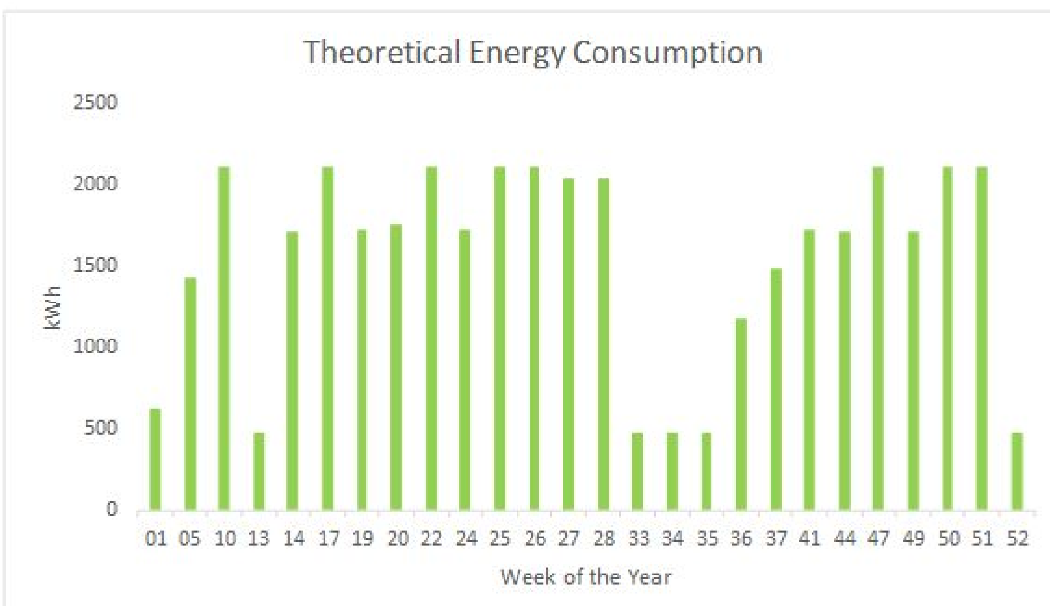

Figure 9 UPC TR2 Theoretical energy consumption (used data)

After having all this information the dispersion chart (figure 10) was made to check the correlation between the two variables theoretical energy consumption TLC and real energy consumption REC.

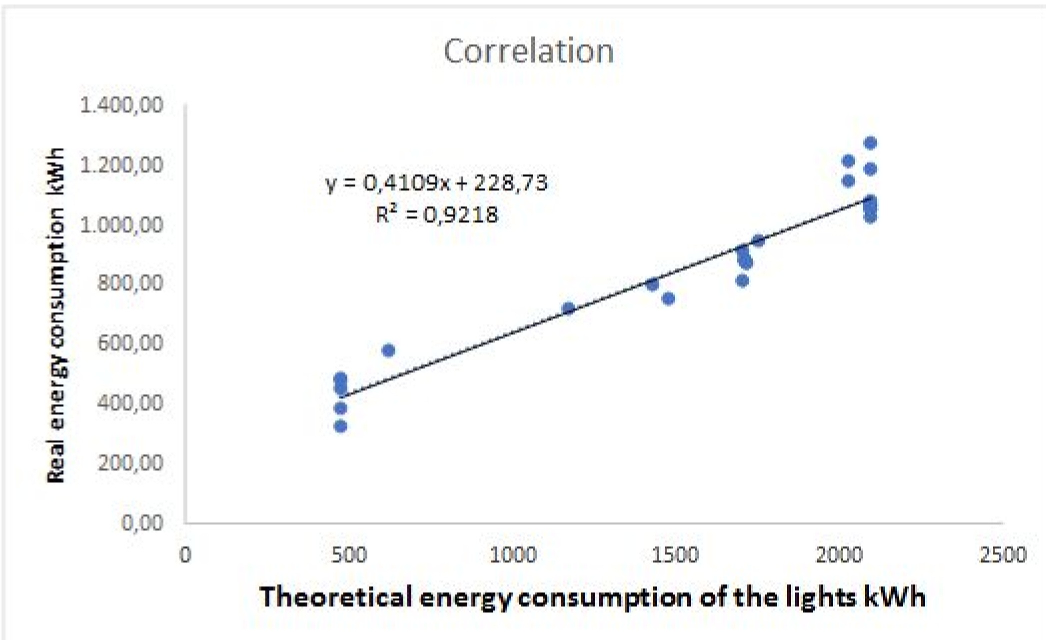

Figure 10 Correlation

It seems that there is a strong correlation as it is shown in figure 9 between the two variables TLC and REC, but is better to make more calculations to confirm the strong correlation between the two variables. TLC is the independent variable on the X-Axis, and the REC is the dependent variable on the Y-Axis. It is required to calculate the covariance and then calculate the Pearson correlation coefficient for accept or reject the H_0.

H_0= The two variables in this study are independent.

H_a= The two variables in this study are related.

$$Sxy = \frac{\sum(Xi - Xm)(Y\,i - Y\,m)}{n-1}$$

$$Sxy = \frac{\sum(Xi - 1539)(Y\,i - 269)}{26-1}$$

$$Sxy = 155794$$

With this result, it is possible to calculate now the Pearson correlation coefficient and if it is higher than 0,8, H_0 will be rejected and confirm that they are a relationship between these two variables.

$$r^2 = \frac{Sxy}{SxSy}$$

$$r^2 = \frac{155794}{628*268} = 0,92$$

Table 14.

Correlation information

n	26
Mean y	861,20
Deviation y	268,73
Mean x	1539,36
Seviation x	627,97
Cov	155794,31
Corr [r]	0,96

The table 14 shows all the result of these calculations, the square root of 0,92 is the Pearson correlation coefficient and was 0,96. Meaning that there is a strong correlation between TLC and REC that rejects the H_0. But before to make other calculations it was decided to create a linear regression in Excel and if the P-value is less than 0,05. For reject without any doubts the H_0.

Resumen

Estadísticas de la regresión	
Coeficiente de correlación múltiple	0,960111505
Coeficiente de determinación R^2	0,921814102
R^2 ajustado	0,918556356
Error típico	76,69241124
Observaciones	26

ANÁLISIS DE VARIANZA

	Grados de libertad	Suma de cuadrados	Promedio de los cuadrados	F	Valor crítico de F
Regresión	1	1664297,442	1664297,442	282,960726	8,73223E-15
Residuos	24	141161,4226	5881,725941		
Total	25	1805458,865			

	Coeficientes	Error típico	Estadístico t	Probabilidad	Inferior 95%	Superior 95%	Inferior 95,0%	Superior 95,0%
Intercepción	228,7272763	40,49619274	5,648118028	8,1428E-06	145,1472423	312,3073102	145,1472423	312,3073102
Variable X 1	0,410871476	0,024425469	16,8214365	8,7322E-15	0,360459786	0,461283167	0,360459786	0,461283167

Figure 11 Linear regression

After doing the linear regression at it is shown in figure 11, it confirms the accuracy of all previous calculations. There is a significant positive relationship between the TCL and REC $r(24) = 0,96$, $P<0,05$. Concluding by the P-value that is much less than 0,05 that it is possible to reject the H_0 and accept the H_a meaning that there is a correlation between these two variables. Also, taking the interception and total that represent here the variable X it confirms the equation given before by the dispersion graphic.

$$Yi = 0,4109Xi + 228,73$$

This equation says that for every kW spent it of theoretical energy consumption of the lights the real energy consumption is increasing by 0,4109. Also, if the lights are switched off, the consumption will be 228,73 kW. Because there are other equipments that spent electricity like computers.

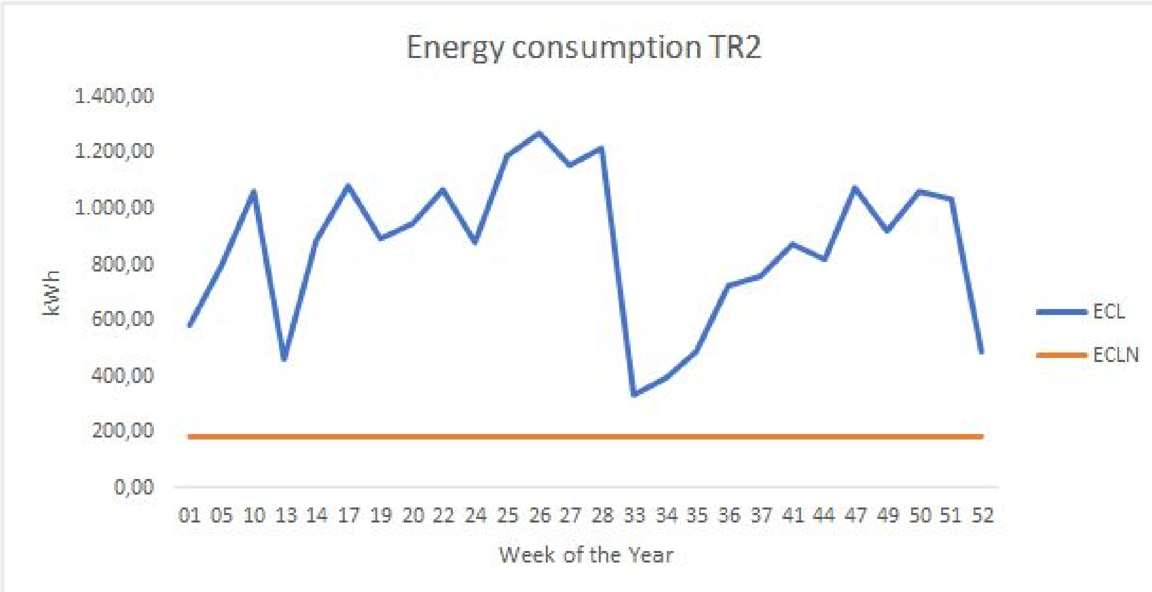

Figure 12 Energy consumption TR2

As figure 12 shows the energy consumption of the lights ECL and the energy consumption without lights ECLN. When there is more activity in a week in the UPC the energy consumption increase a lot and this is because of the energy consumption of the lights. The energy consumed by the lights is 73% of the total energy consumption of the building TR2. It is required to implement a new illumination system to reduce in a great way the energy consumption. Also, it is important to note that these calculations are only for the electricity, not include the gas energy consumed.

5.1.3.2 Cost of energy consumption of the lights in a year

To calculate the cost of energy consumption is was taken every month of the year 2018. Also, it was taken the information of the total energy consumption of the electricity from

SIRENA. Then multiplied by 73% that is the percentage that it was found before that belongs the energy light consumption. After this, It was required to multiplied by the general price of the KW/H given by the government of Spain that is 0.13236 €/KWH. The UPC does not give us the information of what customer supplies their electricity, that is why the calculations are with the general price. The table 15 and figure 13 shows all the information related to the cost of energy consumption.

Table 15.
Cost

Year	Month	Real energy consumption (kWh)	Lights Consumption (kWh)	Cost Real energy consumption (kWh)	Cost Lights Consumption (kWh)
2018	January	3.681,58	2703,78	€ 487,29	€ 357,87
2018	Febraury	3.704,96	2720,95	€ 490,39	€ 360,14
2018	March	3.969,55	2915,27	€ 525,41	€ 385,86
2018	April	4.018,55	2951,25	€ 531,90	€ 390,63
2018	May	4.316,80	3170,29	€ 571,37	€ 419,62
2018	June	4.546,74	3339,16	€ 601,81	€ 441,97
2018	July	4.943,72	3630,70	€ 654,35	€ 480,56
2018	August	2.030,69	1491,36	€ 268,78	€ 197,40
2018	September	3.512,16	2579,36	€ 464,87	€ 341,40
2018	October	4.275,41	3139,89	€ 565,89	€ 415,60
2018	November	4.155,55	3051,86	€ 550,03	€ 403,94
2018	December	3.692,45	2711,76	€ 488,73	€ 358,93

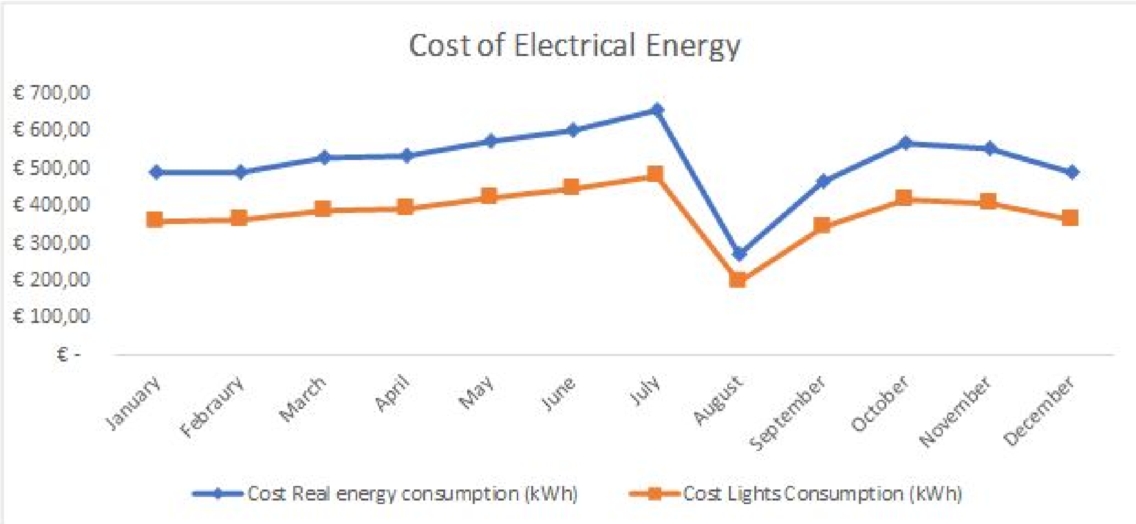

Figure 13 Cost

The graphic of the cost indicates that both costs have the same behavior. Also, the majority of this cost is related to the energy consumption of the lights. Meanwhile, the rest is taken by the equipment used in the TR2. The final step is to calculate the cost of the maintenance. Then, after having all the information it is necessary to make the other study cases and decide which illumination system the UPC should be implemented, or if it is better to stay with the current system.

The information used to calculate the maintenance cost was provided by the maintenance department. The cost will be calculated for one academic year, as explained previously. Also, the prices of the CFL were taken by market research which consisted of searching the internet and the electronic stores in Barcelona. After collecting this information, it was noticed that the prices were different, but similar between the types of lights, so it was necessary to take a mean for each type of light, then this is divided by the lifespan for each place to have the cost per year of the light.

The salary for an electrical technician in Spain is around 19.506 € per year, 1625 € per month, 54 € per day and 6,7 € per hour. While speaking with the maintenance department, they said that they would typically take one hour to change one light. Therefore, in order to calculate the cost to be expected per year for this action. The result is showed in table 13.

$$Maintenance\ cost\ light = \frac{Unitary\ price}{Lifespan}$$

Table 16
Unitary cost CFL

Price Per Unit		Office Price	Classrooms	Hallway Price
Fluorescent 58W	2,48 €	0,43 €	0,16 €	0,94 €
Fluorescent 36W	2,07 €	0,36 €	0,14 €	0,79 €
Fluorescent 26W	2,89 €	0,50 €	0,19 €	1,10 €
Fluorescent 18W	1,96 €	0,34 €	0,13 €	0,75 €
Fluorescent 14W	2,50 €	0,43 €	0,16 €	0,95 €
Electrical Technician	6,70 €	1,16 €	0,44 €	2,55 €

Now, these values are multiplied by the quantity of lights in each place, after that it will show the total maintenance cost per year, it is on table 17.

Table 17
Total cost CFL

TR2	Fluorescent 58W	Fluorescent 36W	Fluorescent 26W	Fluorescent 18W	Fluorescent 14W
Offices	244,97 €	32,64 €	- €	11,23 €	- €
Classrooms	6,54 €	1,64 €	- €	- €	18,80 €
Hallways	21,72 €	58,22 €	42,92 €	0,75 €	- €
Electrical Technician	738,17 €	299,95 €	99,50 €	40,93 €	50,38 €
Total	1.011,41 €	392,44 €	142,42 €	52,91 €	69,18 €

The total amount for the maintenance cost is per year is 1.668,36 €. The cost of the energy consumption of the current lights in a year is 4.553,93 €.

The total cost of the current illumination system is: 1.668,36 + 4.553,93 € = 6.222,29 €.

5.1.3.3 Lights automatization

Before starting this case was necessary to take samples in the building TR2, that consists of how much time do people spend in the hallway of the building. The implementation of the sensor only would be in the hallways, in the classrooms and office are the teachers and students responsibility.

The samples are divided by floor and each floor has two sections right and left, in every section was taken 5 samples of 1 hour. Also, the number of times the lights went on was counted. The sensor would turn off the lights after 10 seconds without detecting any movement. So it is necessary to multiply this value per 10 and then sum to the total time that the lights were on.

Table 18
Summary samples

Floor	Hall	Total hours	Total time (M)	Mean (M)
0	Right	5	27,1	5,42
0	Left	5	70,04	14,01
1	Right	5	61,8	12,36
1	Left	5	78,5	15,70
2	Right	5	29,66	5,93
2	Left	5	28,18	5,64

Table 18 is a summary of the samples to know all the information of the samples checks the annexes.

With this information, it was possible to calculate the mean where the lights were on per floor, after that, with the theoretical energy consumption, it is possible to calculate the energy consumption with the sensor and the percentage of reduction of energy consumption because of the implementation of the sensor. For this study is not used the real energy consumption due to there being too many lights that are switched off in the hallways, that should be on, causing the non-compliance of the legislation of Spain (check annexes).

Table 19
Sensor information

Floor	Mean in minutes per Hour	Energy consumption	Energy consumption with sensor kW/h	% of reduction
0	9,71	1,156	0,19	84%
1	14,03	1,014	0,24	77%
2	5,78	2,86	0,28	90%

The implementation of the sensor would make a great impact on the energy consumption of the lights from the hallways at it shows table 19. Now it is necessary to calculate how much this will cost and how long it will take for the UPC to recover the investment.

Many types of sensor are available in today's market, it was necessary to find one type of sensor that could work perfectly with the case study. It was found 4 types of sensors that are perfect for this case, a detector sensor S1140, S1160, S1180 and presence sensor by microwave S2000 (check the annexes to see all information for each sensor). All these sensors had a detector of natural light, that meant that if there was a lot of sunlight in the hallways, the lights would be off or on in a low intensity. The best option was the S1180 because cover the major distance of detection and is the cheapest option with S1140, a summary of the specification are in table 20.

Table 20
Sensor technical information

Sensor	S1140	S1160	S1180	S2000
Maximun power	300W	300W	300W	300W
Distance detection	6M	9M	12M	10M
Consumption (working)	0,45W	0,45W	0,45W	0,45W
Consumption (stop)	0,1W	0,1W	0,1W	0,1W
Cost	7,95 €	9,95 €	7,95 €	11,95 €

5.1.3.4 Cost of the implementation of sensor

Covering the ground and the first floor required 4 sensors, and the second floor required 10. This is because the hallway of the second floor contained too many lights of 36 Watts, making it necessary to have more sensors because they have maximum capacity is 300 Watts. The operation cost is not included because when the sensor is working or stop the consumption of energy is really low making the cost insignificant. The total investment for implementing the sensors would be 143,10 € plus the 18 hours that it will take for the maintenance department to have them installed, which adds 120,6 € to the cost. Now, is required to calculate the NPV and the IRR to know if this would be a worthwhile investment for the UPC, using the information of table 21.

Table 21
Sensor Cost energy consumption

Floor	Mean minutes	Energy consumption kW/h	Energy consumption with sensor kW/h	Energy saving	Money saving
0	9,71	4402,05	712,67	3689,38	€ 488,33
1	14,03	3861,31	902,92	2958,39	€ 391,57
2	5,78	10890,88	1049,94	9840,94	€ 1.302,55

$$NPV = \left(-263,70 + \frac{2182,95}{(1+0,10)^1} + \frac{2182,95}{(1+0,10)^2} + \frac{2182,95}{(1+0,10)^3} + \frac{2182,95}{(1+0,10)^4} + \frac{2182,95}{(1+0,10)^5}\right)$$

$$NPV = 8009,48\ €$$

The result is greater than 0, meaning that this project will increase the benefits for the UPC in a very significant way. The UPC will not violate the legislation of Spain whilst making these changes, as this sensor detects natural light, so it can ensure the hallways will always have the necessary light to be used by the students and professors of the university. Now it is required to evaluate if it is a good option for the UPC to accept the project. For this, it was calculated the IRR that makes the VPN 0.

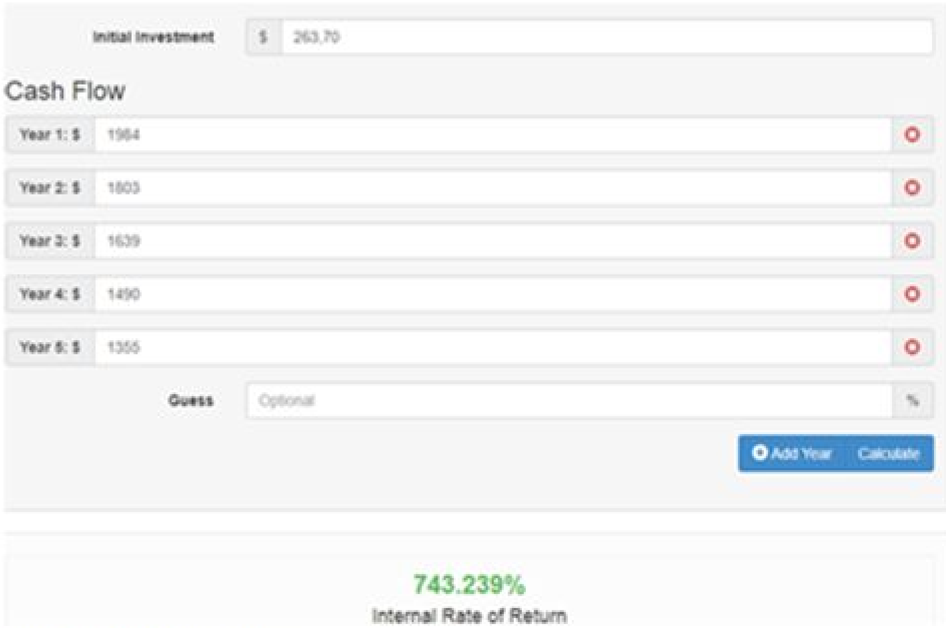

Figure 14 IRR sensor case

Figure 14 shows the calculation of the IRR was calculated by the cash flows and the initial investment making the VPN equal to zero, the result was a 743% rate of return. This is significantly higher than the interest rate, meaning that UPC should accept this project as soon as possible.

5.1.3.5 New illumination

For this case study, it was required to use the real energy consumption of the lights to produce the most accurate results using SIRENA. With the real situation of the energy system of the TR2 building. The first step was to count the quantity of lights that there were, by how many Watts they used per hour. After that, it was carried out market research to find out how much each type of light cost. Then it was calculated the theoretical amount of energy consumption that produces each quantity of light in one hour. This was necessary in order to calculate the percentage of energy consumption from each type of light. Then totaled all the energy consumption and divided this by the energy consumption of each type of light. The percentage was multiplied by the total real energy consumption of the lights, giving us the quantity of real energy consumption for each type of light at is shown in table 22.

5.1.3.6 Cost of old lights

After these calculations, it was necessary to multiply the cost of each type of light with their price to know how much the illumination system of UPC cost. Also, it was required to multiply the general price of the kWh given by the government of Spain that is 0.13236 €/kWh with the total real energy consumption, to know exactly how much the system cost per year, at it is shown in the table 22.

Table 22
General information of CFL

Type of light	Number of lights	Cost of light	Energy consumption kW/h	% of energy consumption	Real energy consumption Kw/year	Total cost of lights	Total cost of real energy consumption
Fluorescent 58W	632	€ 2,48	36,656	0,79	27268,58	€ 1.567,36	€ 3.609,27
Fluorescent 36W	177	€ 2,06	6,372	0,14	4740,16	€ 364,62	€ 627,41
Fluorescent 26W	39	€ 2,89	1,014	0,02	754,32	€ 112,71	€ 99,84
Fluorescent 18W	34	€ 1,96	0,612	0,01	455,27	€ 66,64	€ 60,26
Fluorescent 14W	114	€ 2,50	1,596	0,03	1187,27	€ 285,00	€ 157,15

Another market research gave us the equivalence between the CFL and LED ones, they produce the same quantity of lux or illumination but consuming fewer Watts per hour. These are the newest technologies for an illumination system, and it is more expensive to have these types of lights. So, the purpose of this study is to show if it is rentable for the UPC made the change from CFL to LED lights.

5.1.3.7 Cost of the LED lights

After knowing the cost per unit for each type of light, the next step is to calculate the percentage of Watts reduction and the real energy consumption for each LED light.

$$\%\ watts\ reduction = \frac{CFLwatts - LEDwatts}{CFLwatts}$$

$$\%\ watts\ reduction = \frac{58watts - 22watts}{58watts} = 62\%$$

$$LED\ Light\ Consumption = REC - (REC * \%Watts\ Reduction)$$

$$LED\ Light\ Consumption = 27268{,}58 - (27268{,}58 * 62\%) = 10343{,}26\ Kw/year$$

After that was required to calculate all the cost of this new illumination system, the first step was to calculate the total cost of purchase each type of light. Then the cost of installation of each light that is required one hour of work for the electrician that cost 6,7 € per hour. The third step was to calculate was the total cost of the energy consumption for each type of light. After taking this result and subtracting it from the real energy consumption cost of the CFL, that gave us the total saving per year at it is shown in table 23.

Table 23
General information of LED

Type of light	Number of lights	Cost of light	% of W reduction	Real energy consumption kW/year	Total cost of lights	Cost of installation	Cost real energy consumption	Total saving cost per year
Led 22W	632	€ 9,00	62%	10343,26	€ 5.688,00	€ 4.234,40	€ 1.369,03	€ 2.240,24
Led 18W	177	€ 7,00	50%	2370,08	€ 1.239,00	€ 1.185,90	€ 313,70	€ 313,70
Led 18W	39	€ 6,65	31%	522,22	€ 259,35	€ 261,30	€ 69,12	€ 30,72
Led 10W	34	€ 5,38	44%	252,93	€ 182,92	€ 227,80	€ 33,48	€ 26,78
Led 9W	114	€ 5,07	36%	763,25	€ 577,98	€ 763,80	€ 101,02	€ 56,12

Taking the lifespan of the LED lights that are around 50.000 hours it was necessary to calculate the expected cost per year for each type of light and the expected cost of the electrical technician. This result was obtained by taking the expected amount of hours used in a year for each part of the TR2 building and then dividing by the 50.000 to know how much the lifespan of the LED light was affected. This result is multiplied by the price per unit, giving us the unitary cost of LED in table 25.

Table 24.
LED lights lifespan

TR2	Lifespan (years)
Offices	29
Classrooms	76
Hallways	13

$$Maintenance\ cost\ light = \frac{Unitary\ price}{Lifespan}$$

Table 25
Unitary cost of LED

Price Per Unit		Office Price	Classrooms Price	Hallway Price
Led 22W	9,00 €	0,28 €	0,12 €	0,69 €
Led 18W	7,00 €	0,22 €	0,09 €	0,53 €
Led 18W	6,65 €	0,21 €	0,09 €	0,51 €
Led 10W	5,38 €	0,17 €	0,07 €	0,41 €
Led 9W	5,07 €	0,16 €	0,07 €	0,39 €
Electrical Technician	6,70 €	0,21 €	0,09 €	0,51 €

After having this cost per unit, it was necessary to multiply all these values with the quantity of light that have each zone of the TR2 building. This will give us the total cost of maintenance per year of the LED illumination system.

Table 26
Total cost of LED

TR2	LED 22W	LED 18W	LED18W	LED 10W	LED 9W
Offices	158,96 €	19,77 €	- €	5,51 €	- €
Classrooms	4,75 €	1,11 €	- €	- €	7,62 €
Hall	15,77 €	39,45 €	19,75 €	0,41 €	- €
Electrical Technician	133,61 €	57,75 €	19,90 €	7,37 €	10,08 €
Total	313,08 €	118,08 €	39,65 €	13,29 €	17,70 €

The total amount for the maintenance cost is per year of the old system was 1.668,36 €, the table 26 shows that the maintenance cost per year of the new system is 501,80 €, so this means other saving cost of 1.166,56 € per year.

To know if the investment for this project is going to be rentable for the UPC, it is necessary to calculate the NPV. Having the total amount of investment of 14.620,45 € and the earning of the project will be the saving cost that is a total of 3.316,90 €+1.166,56 € = 4.483,46

€. The number of years that it was taken 20 and this is because the new illumination system will last around 20 years.

$$NPV = \left(-14.620,45 + \frac{4.483,46}{(1+0,10)^1} + \frac{4.483,46}{(1+0,10)^2} + \frac{4.483,46}{(1+0,10)^3} + \ldots + \frac{4.483,46}{(1+0,10)^{20}}\right)$$

$$NPV = 23.549,75\ €$$

The result gave us an NPV positive, which means that there are earnings at the end of the project for the UPC, before deciding that this project is good for UPC, it was necessary to calculate the IRR, to accept or reject the project. It is also important to emphasize that now the UPC is not complying to the legislation of Spain, because some parts of the TR2 building are too dark, due to a lot of lights being off. So, if these lights were on, the real energy consumption of the lights would be higher and then the savings cost also would be higher, giving a higher NPV-

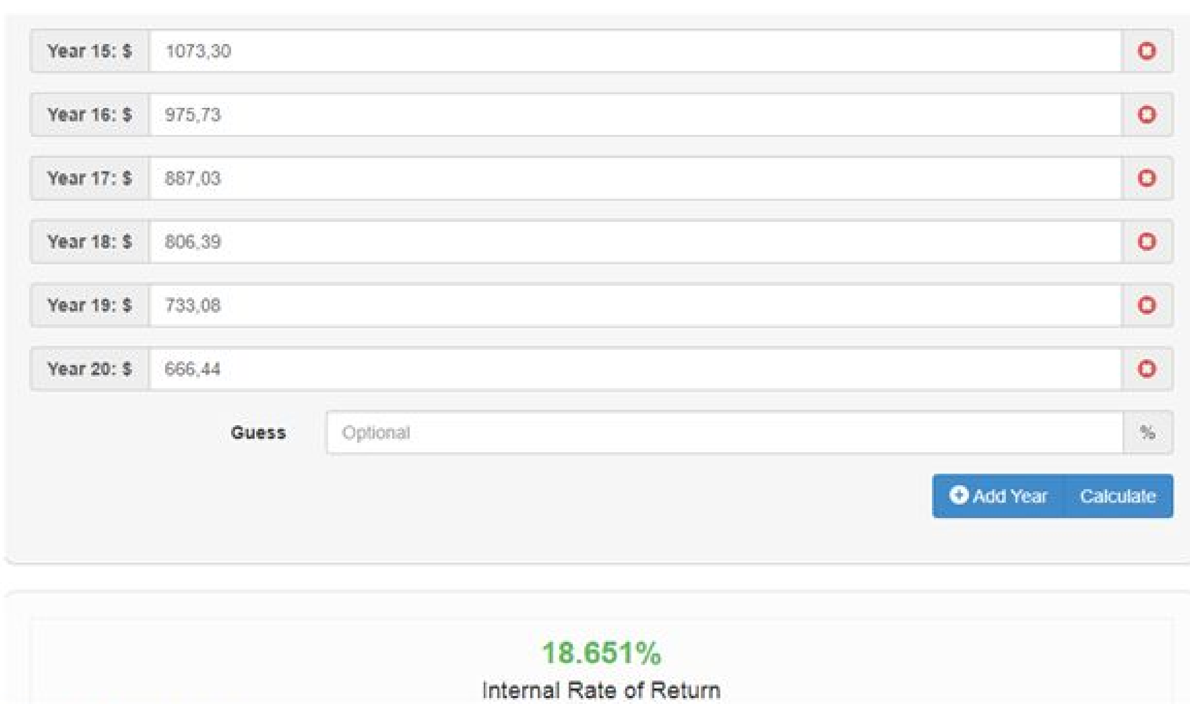

Figure 15 IRR LED case

The figure 15 shows that IRR was calculated and the result was 18.651% so this means that the project should be accepted because the discount rate is lower than the IRR, and it would be a good investment for the UPC.

5.1.3.8 New illumination and automatization

The last case study is a combination of the second and the third case because one of the most important factors for the UPC is to reduce as much as possible the energy consumption in their buildings. So, mixing these two ideas will give us the largest possible energy reduction consumed by the lights.

5.1.3.9 Cost of the project

With the data that was collected previously and some changes for the quantity of sensor because with the LED lights the watts are less making that each sensor can support more lights, 2 for the ground floor, 3 for floor 1 and 5 for floor 2. Now it is possible to calculate the VPN immediately because the investment will be 14.620,45 € from the (LED) system plus 146,5 € for the sensor system giving us a total investment of 14.766,95 €.

Table 27.

LED and sensor information

Floor	LED % of Watts reduction	LED Energy consumption kW/h	Energy consumption with sensor and LED kW/H	Energy saving kW/h	Money saving
0	62%	2729,27	441,85	2287,42	€ 302,76
1	31%	1197,01	279,91	917,10	€ 121,39
2	50%	5445,44	524,97	4920,47	€ 651,27

Then the earnings will be the saving cost of 4.483,46 € from the (LED) system plus 1.075,42 € of the sensor system implemented with LED lights. But this will only be in the first five years because the lifespan for these types of products to take this quantity of time. The other 15 year's the saving cost would only be the 4.483,46 € of the (LED) project.

$$NPV = \left(-14.766,95 + \frac{5.588,88}{(1+0,10)^1} + \frac{5.588,88}{(1+0,10)^2} + \frac{5.588,88}{(1+0,10)^3} + \frac{5.588,88}{(1+0,10)^4} + \frac{5.588,88}{(1+0,10)^5} + \frac{4.483,46}{(1+0,10)^6} + \ldots + \frac{4.483,46}{(1+0,10)^{20}}\right)$$

$$NPV = 27.479,95\ €$$

This NPV is higher than the previous project, making it more attractive for the UPC, as their priority is to reduce as possible the energy consumption within their buildings in 2020. So, this project appears to be the most useful for the UPC. But first, it is required to calculate the IRR to finally accept or reject the project.

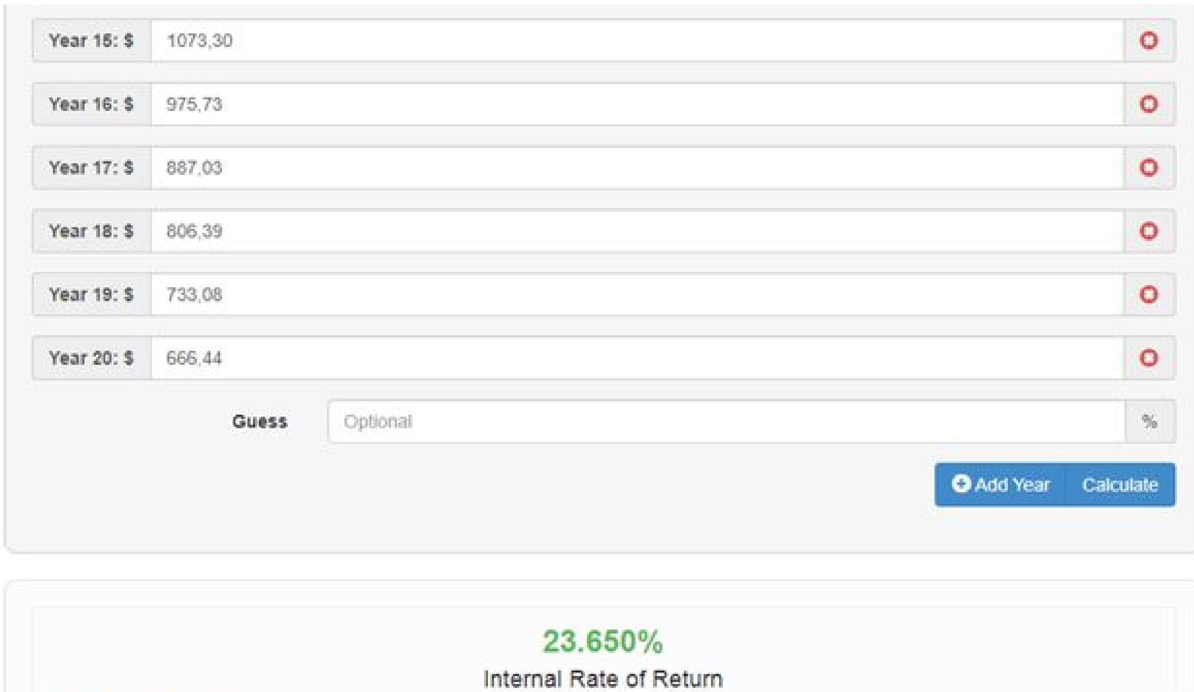

Figure 16 IRR LED sensor case

Figure 16 shows that the IRR is higher than the discount rate that is 10%. Also higher than in the past case. So the UPC should accept this project because this project will be profitable for the UPC and would help to accomplish the reduction of energy consumption that UPC wishes to implement.

5.1.4 Environment impact

One of the objectives of this project is to quantify the reduction of CO_2 emissions that can bring the change of the illumination system. Because the UPC want to be more eco-friendly and this will give them better social imagine. Study 4 is taken (new illumination and automatization) because this project shows the major quantity of reduction of CO_2 emissions.

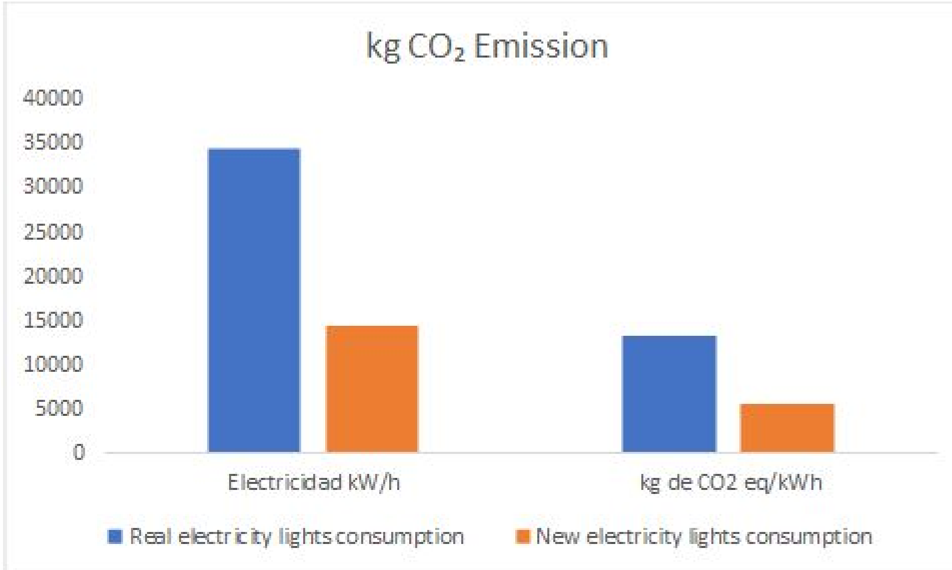

Figure 17 kg CO_2 Emission

With the LED lights and the implementation of the sensor is a reduction of CO_2 emissions in 59% from 13246 kg of CO_2 to 5486 kg of CO_2 at it shows the figure 17. Making these changes to the illumination system of the building TR2 will contribute in a huge way to the environment, less electricity used less CO_2 emission are produced. Also, the LED lights do not use mercury as the CFL used and this material is very dangerous for the environment. Every CFL contains 4 mg of mercury and currently, UPC has a total of 996 CFL lights. Meaning that if they change to LED lights they will reduce 3,98g of mercury.

Conclusion

In recent times, energy consumption plays a fundamental role in the pollution of the environment. Because producing quantities of energy provoke more greenhouse gas emission, causing an increase in the temperature of the earth, damaging ecosystems. There are some treatments of the European Union calling for an attempt to control greenhouse gas emission. This is one of the main reasons that UPC wants to reduce its energy consumption.

After all, the research was carried out and the calculations from the past studies were taken into consideration. It concluded that the best option to follow for the UPC is to changes all their current light system for LED and install the occupancy sensor for the hallways of the TR2 building. This will have the most possible reduction in the energy consumption of the TR2 building. Also, the installation of these two systems is going to create earnings for the UPC and the investment can be recovered over a relatively short period of time.

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Annexes

Floor	0	Right hall	Sensor 10s
Schedule	Time (M)	Number of times lights on	Total time
1pm-2pm	1,43	8	2,77
2pm-3pm	1,53	6	2,53
3pm-4pm	2,00	4	2,67
4pm-5pm	10,50	20	13,83
5pm-6pm	3,80	9	5,30

Floor	0	Left hall	Sensor 10s
Schedule	Time (M)	Number of times lights on	Total time
3pm-4pm	18,13	60	28,13
4pm-5pm	1,73	8	3,07
5pm-6pm	9,73	28	14,40
6pm-7pm	7,10	20	10,43
7pm-8pm	9,17	29	14,00

Floor	1	Right hall	Sensor 10s
Schedule	Time (M)	Number of times lights on	Total time
2pm-3pm	1,93	8	3,27
3pm-4pm	4,37	16	7,03
4pm-5pm	4,27	20	7,60
5pm-6pm	3,50	15	6,00
6pm-7pm	3,93	11	5,76

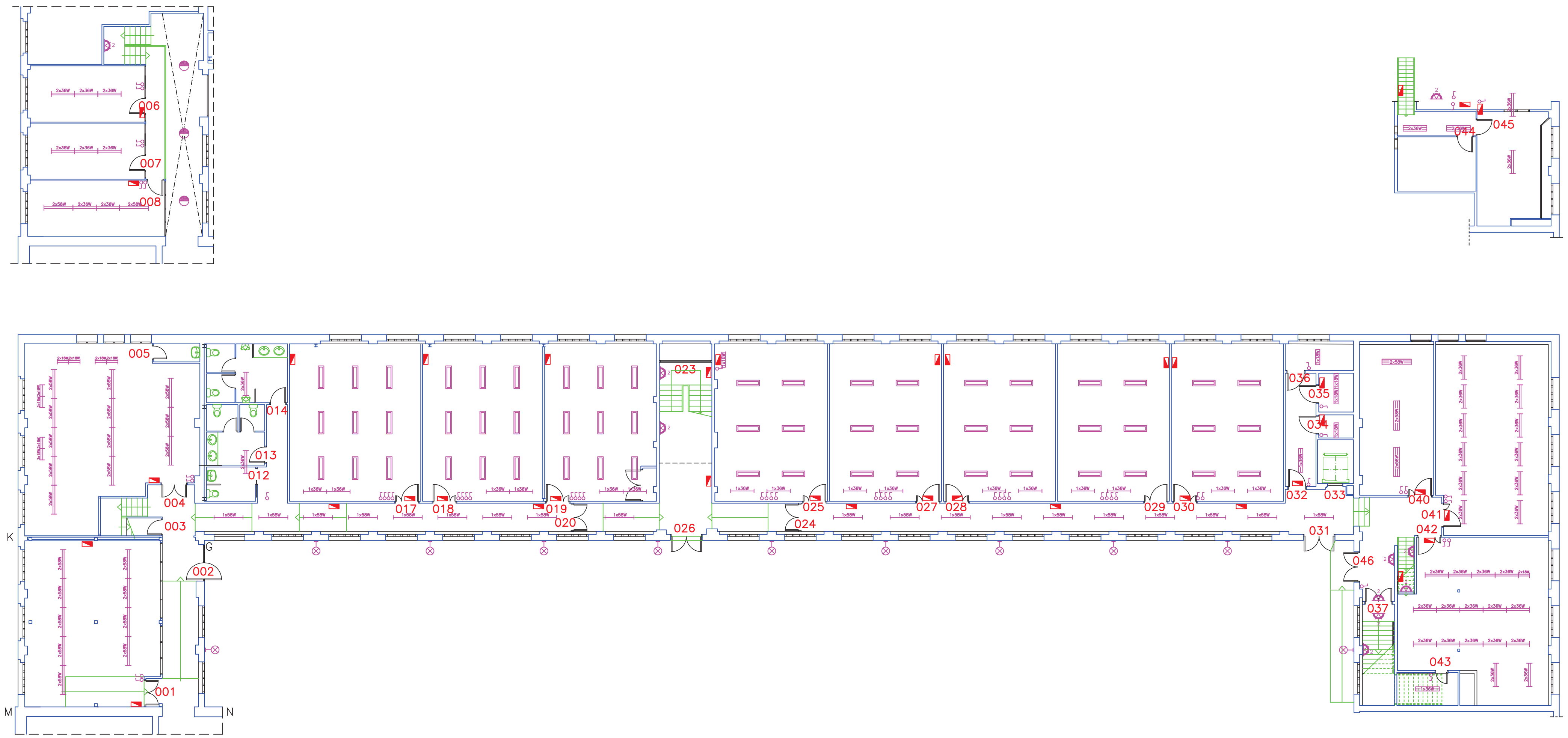
Floor	1	Left hall	Sensor 10s
Schedule	Time (M)	Number of times lights on	Total time
8am-9am	9,80	8	11,13
9am-10am	0,87	6	1,87
10am-11am	2,37	6	3,37
11am-12pm	4,34	7	5,51
12pm-1pm	5,14	7	6,31

Floor	2	Right hall	Sensor 10s
Schedule	Time (M)	Number of times lights on	Total time
10am-11am	5,57	18	8,57
11am-12pm	7,43	32	12,77
12pm-1pm	6,50	25	10,67
1pm-2pm	11,27	27	15,77
2pm-3pm	9,70	26	14,03

Floor	2	Left hall	Sensor 10s
Schedule	Time (M)	Number of times lights on	Total time
3pm-4pm	6,47	22	10,13
4pm-5pm	5,43	19	8,60
5pm-6pm	7,87	28	12,53
6pm-7pm	10,40	32	15,73
7pm-8pm	26,17	32	31,50

Hallway TR2 ground floor

Hallway TR2 second floor



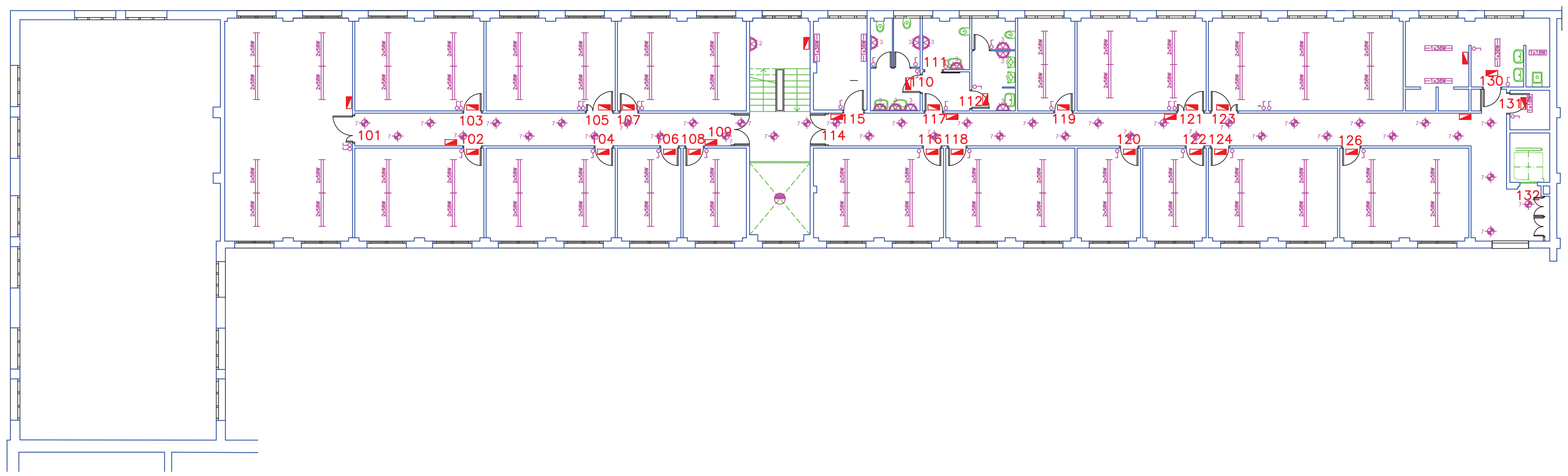
leyenda electricidad

- Aplique escalera TR7
- Aplique escalera TR9 / TR2 / TR3
- Aplique lavabo TR2
- Aplique decorativo con 3 lámparas esféricas
- Aplique decorativo con 1 lámpara esférica
- Aplique decorativo con 7 lámparas esféricas
- Aplique exterior con rejilla protectora
- Aplique con difusor luz indirecta
- Aplique exterior con pedestal TR1
- Aplique exterior 1x100W (incandescente)
- Aplique exterior tipo globo (1X150W)
- Aplique exterior bola
- Foco exterior 1x400W
- Luminaria de emergencia
- Down Light 1x18W
- Down Light 2x26W
- Down Light 1x26W
- Aplique de superficie 2x26W
- Pantalla estanca 2x58W
- Pantalla estanca 2x36W
- Pantalla estanca 1x36W
- Pantalla estanca 1x18W
- Regleta fluorescente 1x58W
- Regleta fluorescente 2x36W
- Regleta fluorescente 1x36W
- Regleta fluorescente 2x18W
- Regleta fluorescente 1x18W
- Potenciómetro

leyenda electricidad

- Luminaria lineal encadenada (2x58W)
- Luminaria lineal encadenada (1x58W)
- Luminaria lineal encadenada (3x36W)
- Luminaria lineal encadenada (2x36W)
- Luminaria lineal encadenada (1x36W)
- Luminaria lineal encadenada (2x18W)
- Luminaria lineal encadenada (1x18W)
- Aplique fluorescente 1x18W
- Linestra lavabo 1x 18W
- Halógeno 1x50W
- Campana grande
- Pantalla empotrada 2x14 (tubo fino)
- Pantalla 4x36W
- Pantalla 3x36W
- Pantalla 2x36W
- Pantalla 4x18W
- Pantalla 3x18W
- Pantalla superficie
- Pantalla redonda superficie (3x26W)
- Down Light lámpara bajo consumo
- Aplique fluorescente ascensor
- Aplique fluorescente
- Foco halógeno 1x150W
- Luminaria suspendida con 4 lámparas esféricas, 12 lámparas bajo consumo y 12 fuorescentes 1x18W
- Interruptor estanco
- Interruptor simple
- Interruptor conmutado

Servei d'Obres i Manteniment UNIVERSITAT POLITÈCNICA DE CATALUNYA	Escala 1/300 0 1,5 3 4,5 6 7,5 9 10,5 12	Data ABRIL 13	Cod. Ed. TR2
Unitat Estructural ESEIAAT	Plànol PLANTA 0		Núm. 0.02



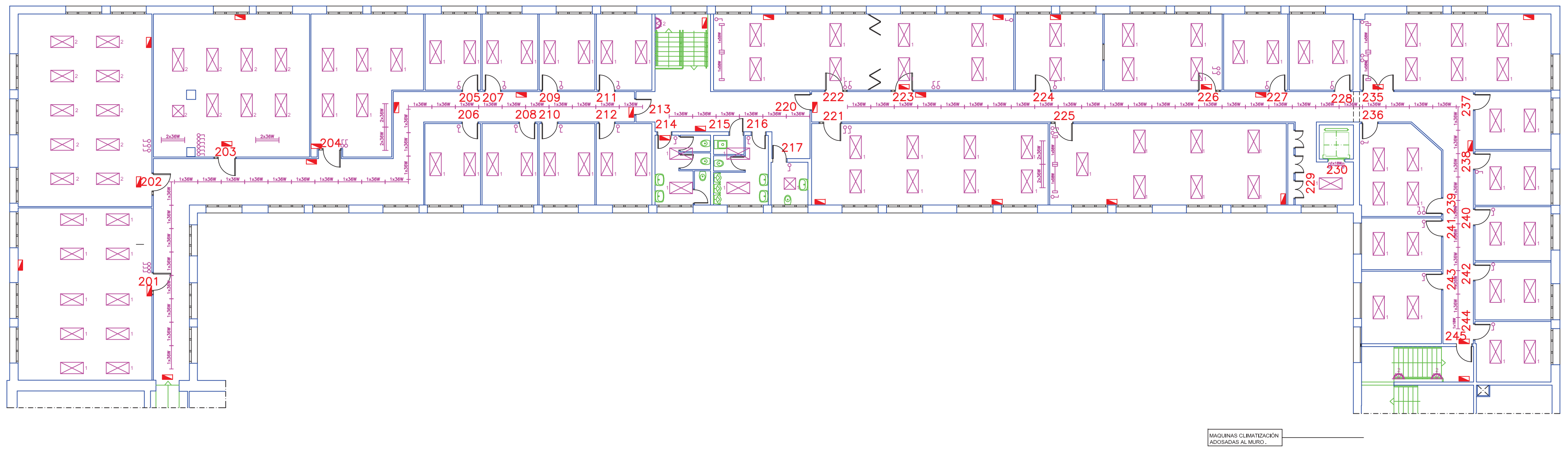
leyenda electricidad

- Aplique escalera TR7
- Aplique escalera TR9 / TR2 / TR3
- Aplique lavabo TR2
- Aplique decorativo con 3 lámparas esféricas
- Aplique decorativo con 1 lámpara esférica
- Aplique decorativo con 7 lámparas esféricas
- Aplique exterior con rejilla protectora
- Aplique con difusor luz indirecta
- Aplique exterior con pedestal TR1
- Aplique exterior 1x100W (incandescente)
- Aplique exterior tipo globo (1X150W)
- Aplique exterior bola
- Foco exterior 1x400W
- Luminaria de emergencia
- Down Light 1x18W
- Down Light 2x26W
- Down Light 1x26W
- Aplique de superficie 2x26W
- Pantalla estanca 2x58W
- Pantalla estanca 2x36W
- Pantalla estanca 1x36W
- Pantalla estanca 1x18W
- Regleta fluorescente 1x58W
- Regleta fluorescente 2x36W
- Regleta fluorescente 1x36W
- Regleta fluorescente 2x18W
- Regleta fluorescente 1x18W
- Potenciómetro

leyenda electricidad

- Luminaria lineal encadenada (2x58W)
- Luminaria lineal encadenada (1x58W)
- Luminaria lineal encadenada (3x36W)
- Luminaria lineal encadenada (2x36W)
- Luminaria lineal encadenada (1x36W)
- Luminaria lineal encadenada (2x18W)
- Luminaria lineal encadenada (1x18W)
- Aplique fluorescente 1x18W
- Linestra lavabo 1x 18W
- Halógeno 1x50W
- Campana grande
- Pantalla empotrada 2x14 (tubo fino)
- Pantalla 4x36W
- Pantalla 3x36W
- Pantalla 2x36W
- Pantalla 4x18W
- Pantalla 3x18W
- Pantalla superficie
- Pantalla redonda superficie (3x26W)
- Down Light lámpara bajo consumo
- Aplique fluorescente ascensor
- Aplique fluorescente
- Foco halógeno 1x150W
- Luminaria suspendida con 4 lámparas esféricas, 12 lámparas bajo consumo y 12 fuorescentes 1x18W
- Interruptor estanco
- Interruptor simple
- Interruptor conmutado

Servei d'Obres i Manteniment UNIVERSITAT POLITÈCNICA DE CATALUNYA	Escala 1/300 0 1,5 3 4,5 6 7,5 9 10,5 12	Data JULIOL 16	Cod. Ed. TR2
Unitat Estructural ESEIAAT	Plànol PLANTA 1		Núm. 0.03



leyenda electricidad

- Aplique escalera TR7
- Aplique escalera TR9 / TR2 / TR3
- Aplique lavabo TR2
- Aplique decorativo con 3 lámparas esféricas
- Aplique decorativo con 1 lámpara esférica
- Aplique decorativo con 7 lámparas esféricas
- Aplique exterior con rejilla protectora
- Aplique con difusor luz indirecta
- Aplique exterior con pedestal TR1
- Aplique exterior 1x100W (incandescente)
- Aplique exterior tipo globo (1X150W)
- Aplique exterior bola
- Foco exterior 1x400W
- Luminaria de emergencia
- Down Light 1x18W
- Down Light 2x26W
- Down Light 1x26W
- Aplique de superficie 2x26W
- Pantalla estanca 2x58W
- Pantalla estanca 2x36W
- Pantalla estanca 1x36W
- Pantalla estanca 1x18W
- Regleta fluorescente 1x58W
- Regleta fluorescente 2x36W
- Regleta fluorescente 1x36W
- Regleta fluorescente 2x18W
- Regleta fluorescente 1x18W
- Potenciómetro

leyenda electricidad

- Luminaria lineal encadenada (2x58W)
- Luminaria lineal encadenada (1x58W)
- Luminaria lineal encadenada (3x36W)
- Luminaria lineal encadenada (2x36W)
- Luminaria lineal encadenada (1x36W)
- Luminaria lineal encadenada (2x18W)
- Luminaria lineal encadenada (1x18W)
- Aplique fluorescente 1x18W
- Linestra lavabo 1x 18W
- Halógeno 1x50W
- Campana grande
- Pantalla empotrada 2x14 (tubo fino)
- Pantalla 4x36W
- Pantalla 3x36W
- Pantalla 2x36W
- Pantalla 4x18W
- Pantalla 3x18W
- Pantalla superficie
- Pantalla redonda superficie (3x26W)
- Down Light lámpara bajo consumo
- Aplique fluorescente ascensor
- Aplique fluorescente
- Foco halógeno 1x150W
- Luminaria suspendida con 4 lámparas esféricas, 12 lámparas bajo consumo y 12 fuorescentes 1x18W
- Interruptor estanco
- Interruptor simple
- Interruptor conmutado

UPC Servei d'Obres i Manteniment UNIVERSITAT POLITÈCNICA DE CATALUNYA	Escala 1/300 0 3 6 9 12	Data MAIG 04	Cod. Ed. TR2
Unitat Estructural ESEIAAT	Plànol PLANTA 2		Núm. 0.04

SENSOR INFRARROJO DE MOVIMIENTO PARA INTERRUPTOR S1160

Este producto le permitirá ahorrar energía gracias a su sensor de movimiento. De esta forma podrá encender y apagar las luces de forma automática.Su sensor infrared permite detectar cuando alguien entra en su campo. Una de las grandes características de este sensor es que es capaz de identificar la luz de noche y día, utilizando así, la energía de vuestros productos LED de una manera más efectiva.

CARACTERÍSTICAS:

Voltaje: 220 -240V/AC
Frecuencia: 50Hz
Sensor lumínico: de 3 a -2000 LUX(ajustable)
Temporizador:
min: 10sec±3sec.
max: 7min±2min
Capacidad nominal:
1200W (bombilla incandescente)
300W(bombilla de ahorro)
Distancia de detección: 9m max(<24′C)
Ángulo de sensor: 160″
Temperatura de trabajo:-20—+40′C
Humedad soportada: <93%RH
Altura recomendad: 1 rn-i .8m
Consumo:
0.45W (en funcionamiento)
0.1W (parado)
Velocidad de detección: 0.6-1 .5m/s
Funciones

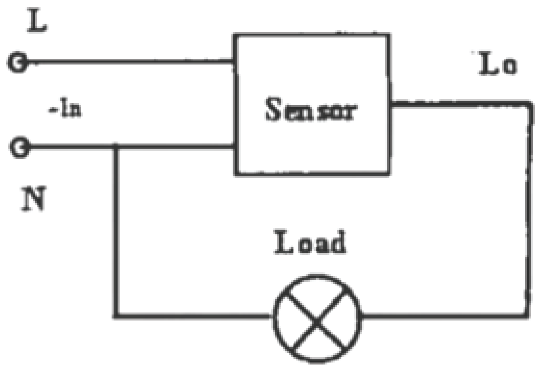
3 modos de función: ON - OFF - PIR
ON: Mantendrá la luz encendida
OFF: Mantendrá la luz apagada
PIR: Función infrarrojo

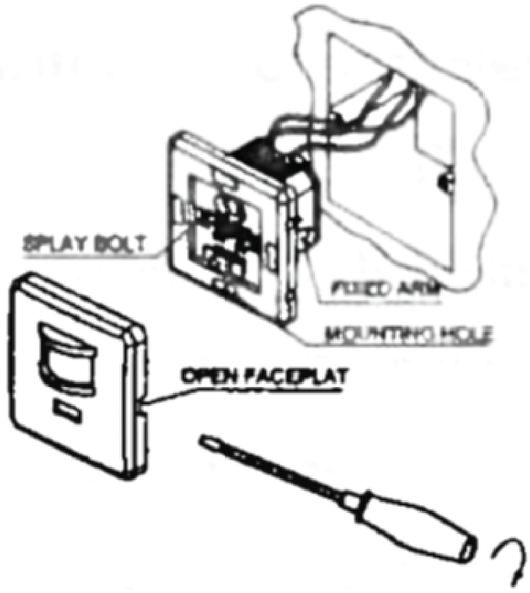
Detecta el día y la noche automáticamente. Puede ajustar el sensor de luz ambiente a su gusto: Ajustar al valor SOL para que funcione durante el día y la noche. Ajustar al valor LUNA para que trabaje en condición nocturna (menos de 3 lux ambiente). Para otras condiciones lumínicas pruebe diferentes ajustes.
La función temporizador añade un retraso temporal para el encendido y apagado.
Time-delay is added continually: when it receives the second induction signal after the first inductor, it will compute time once more on the rest of the first time-delay basic (Set time) .
La función temporizador se puede ajustar entre un valor mínimo de 10±3 segundos y un máximo de 7±2 minutos.

Instalación

- Apague la corriente.

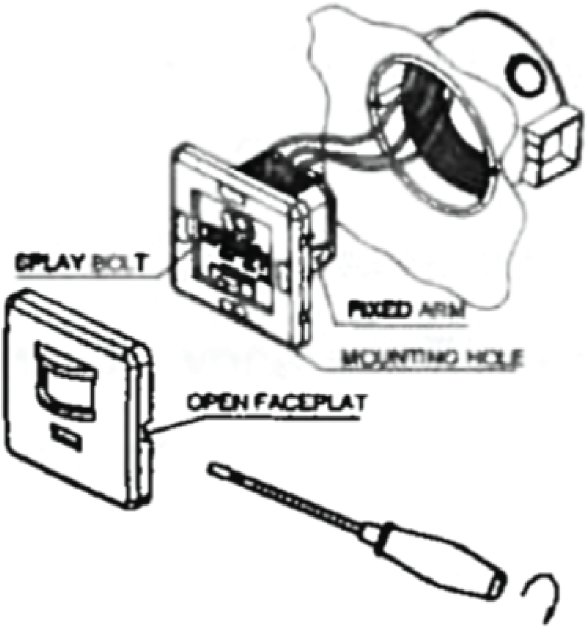
- Afloje los tornillos de conexión para conectar los cables de corriente al sensor según el diagrama inferior y apriete los tornillos de conexión de vuelta.

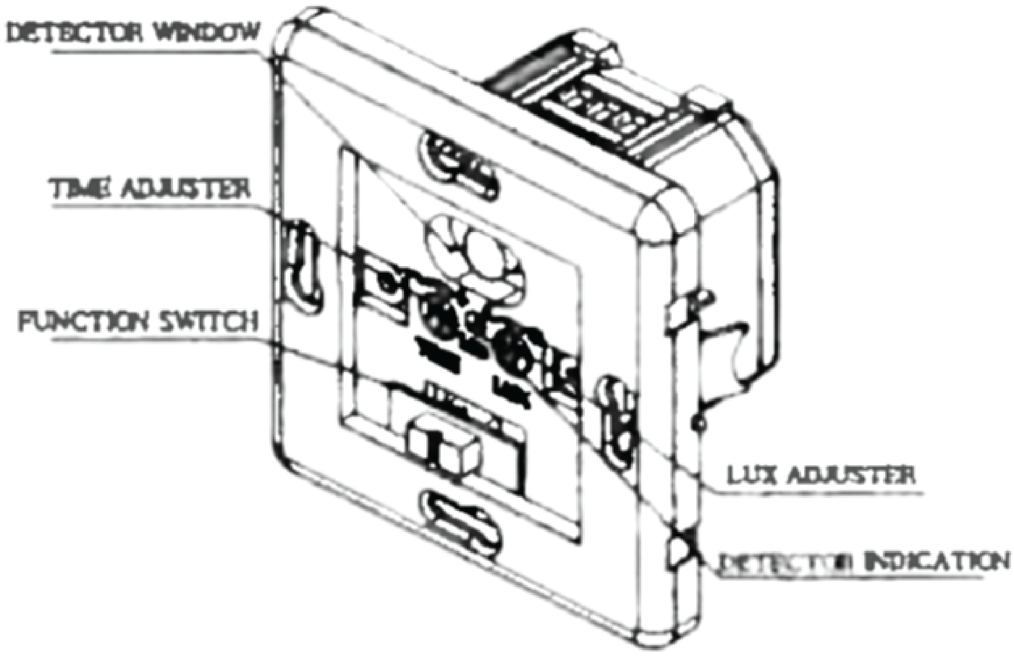




- Introduzca la caja del sensor en al agujero empotrado, encajando las guías a los tornillos de soporte.

- Una vez instalado, conecte la corriente y pruebe el sensor.





Notas:

- Cuando quiera operar el sensor durante el día, ajuste el valor LUX al máximo (posición SOL)
- Fácil instalación para electricistas o personas con experiencia
- No coloque objetos delante del sensor
- Evite su instalación cerca de fuentes de calor o frío (aire acondicionado, calefacción, etc)
- No abra la carcasa protectora después de la instalación

Problemas comunes:

No hay corriente:
a. Compruebe la corriente y voltaje.
b. Asegúrese de que la corriente está activa.
c. Asegúrese de que el interruptor de la luz está encendido
d. Asegúrese de que está en las condiciones lumínicas ajustadas en el valor LUX.

La sensibilidad es débil:
a. Asegúrese de que no hay objetos interrumpiendo el sensor
b. Compruebe la luz ambiente.
c. Compruebe que el sensor esté en posición PIR.
d. Compruebe la altura de instalación.
e. Compruebe la orientación del sensor.

El sensor no apaga la luz:
a. Asegúrese de que no hay ningún objeto activando el sensor
b. Compruebe que el temporizador no esté en su valor máximo.
c. Compruebe que la conexión de cables se correspo.
d.Compruebe que no haya fuentes de calor o frío cerca del sensor.

FOCO CON SENSOR DE MOVIMIENTO S1180

Este producto le permitirá ahorrar energía gracias a su sensor de movimiento. De esta forma podrá encender y apagar las luces de forma automática.Su sensor infrared permite detectar cuando alguien entra en su campo. Una de las grandes características de este sensor es que es capaz de identificar la luz de noche y día, utilizando así, la energía de vuestros productos LED de una manera más efectiva.

CARACTERÍSTICAS
Voltaje: 220 -240V/AC
Frecuencia: 50Hz
Sensor lumínico: de 3 a -2000 LUX(ajustable)
Temporizador:
min: 10sec±3sec.
max: 8min±2min
Capacidad nominal:
1200W (bombilla incandescente)
300W (bombilla de ahorro)
Detection Distance: 12m max(<24ºC)
Ángulo de sensor: 180”
Temperatura de trabajo:-20—+40ºC
Humedad soportada:<93%RH
Altura recomendada: 1 m- 1.8m
Consumo:
0.45W (en funcionamiento)
0.1W (parado)
Velocidad de detección: 0.6-1 .5m/s

Función:
Este producto le permitirá ahorrar energía gracias a su sensor de movimiento. De esta forma podrá encender y apagar las luces de forma automática.Su sensor infrared permite detectar cuando alguien entra en su campo. Una de las grandes características de este sensor es que es capaz de identificar la luz de noche y día, utilizando así, la energía de vuestros productos LED de una manera más efectiva.

Funciones
Campo de detección: El rango de detección puede ser orientado para mejorar su sensibilidad
Detecta el día y la noche automáticamente. Puede ajustar el sensor de luz ambiente a su gusto: Ajustar al valor SOL para que funcione durante el día y la noche. Ajustar al valor LUNA para que trabaje en condición nocturna (menos de 3 lux ambiente). Para otras condiciones lumínicas pruebe diferentes ajustes.
La función temporizador añade un retraso temporal para el encendido y apagado.
Time-delay is added continually: when it receives the second induction signal after the first inductor, it will compute time once more on the rest of the first time-delay basic (Set time) .
La función temporizador se puede ajustar entre un valor mínimo de 10±3 segundos y un máximo de 8±2 minutos.

Instalación: (ver diagrama)

- Apague la corriente.
- Afloje los tornillos de la tapa inferior para acceder a los cables de conexión. Pase los cables de corriente a través del agujero.
- Afloje de conexión para conectar los cables de corriente al sensor según el diagrama inferior y apriete los tornillos de conexión de vuelta.
- Vuelva a colocar la tapa inferior y apriete los tornillos de fijación..
- Una vez instalado, conecte la corriente y pruebe el sensor.

Comprobación:

- Apague la corriente.
- Ajuste el selector de tiempo al mínimo y ajuste la selector LUX al máximo.
- Encienda la corriente, espere entre 5 y 30 segundos y compruebe el correcto funcionamiento del sensor..
- Puede ajustar el selector LUX al mínimo y comprobar su correcto funcionamiento tapando el sensor con algún objeto opaco.
- Recuerde: Al probar el sensor durante el día, ajuste el selector LUX al máximo.

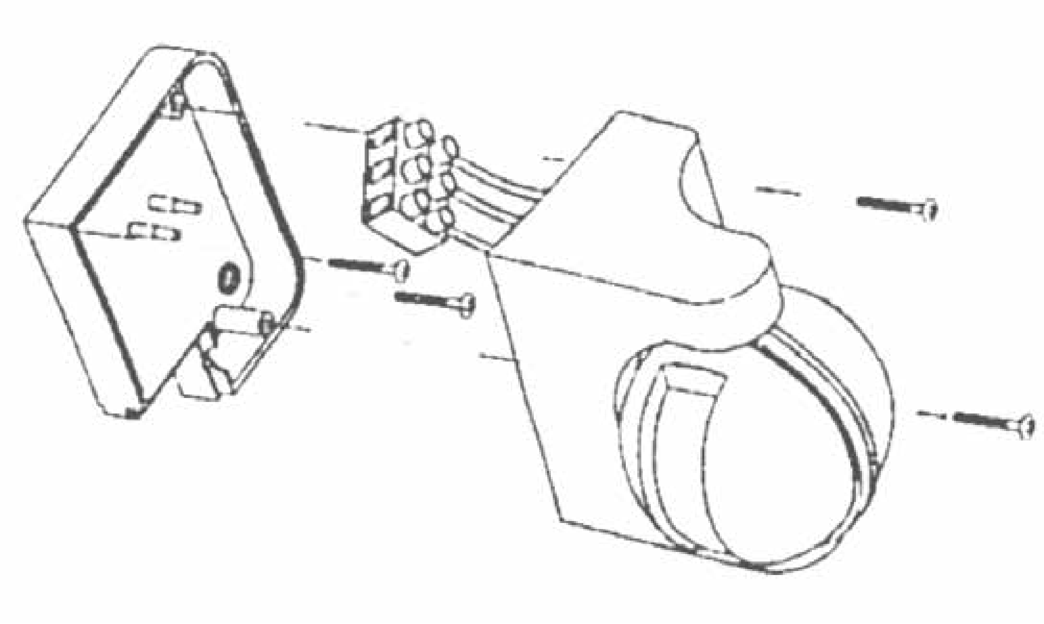
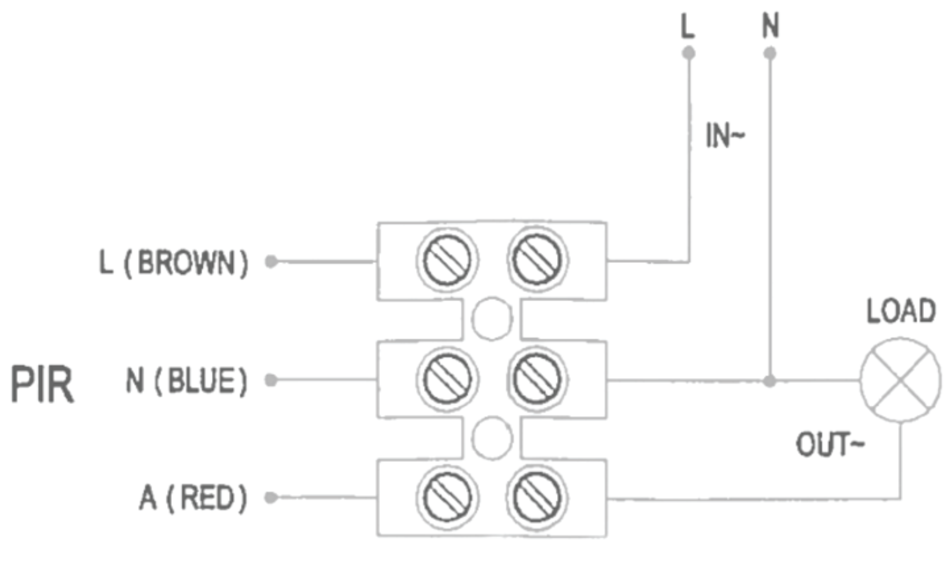


Diagrama de conexión de cables



Notas:

- Cuando quiera operar el sensor durante el día, ajuste el valor LUX al máximo (posición SOL)
- Fácil instalación para electricistas o personas con experiencia
- No coloque objetos delante del sensor
- Evite su instalación cerca de fuentes de calor o frío (aire acondicionado, calefacción, etc)
- No abra la carcasa protectora después de la instalación

Problemas comunes:

No hay corriente:
a. Compruebe la corriente y voltaje.
b. Asegúrese de que la corriente está activa.
c. Asegúrese de que el interruptor de la luz está encendido
d. Asegúrese de que está en las condiciones lumínicas ajustadas en el valor LUX.

La sensibilidad es débil:
a. Asegúrese de que no hay objetos interrumpiendo el sensor
b. Compruebe la luz ambiente.
c. Compruebe que el sensor esté en posición PIR.
d. Compruebe la altura de instalación.
e. Compruebe la orientación del sensor.

El sensor no apaga la luz:
a. Asegúrese de que no hay ningún objeto activando el sensor
b. Compruebe que el temporizador no esté en su valor máximo.
c. Compruebe que la conexión de cables se correspo.
d.Compruebe que no haya fuentes de calor o frío cerca del sensor.

SENSOR DE MOVIMIENTO S1140

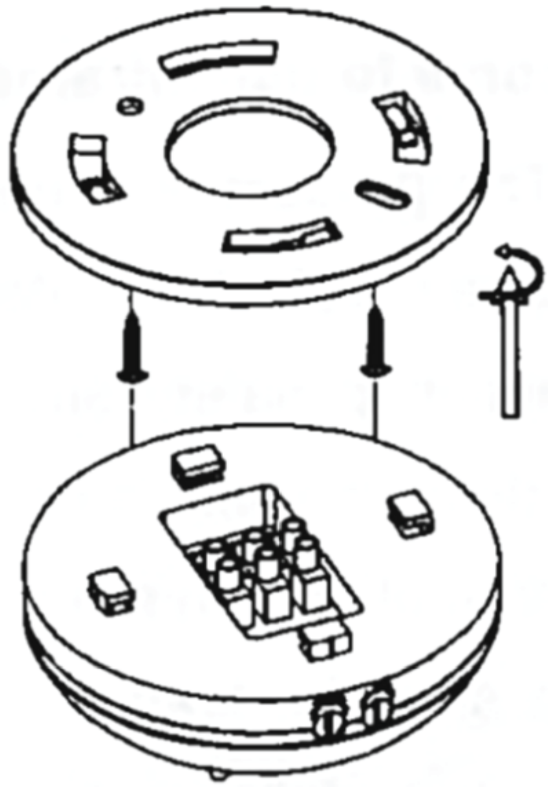
Este producto le permitirá ahorrar energía gracias a su sensor de movimiento. De esta forma podrá encender y apagar las luces de forma automática. Su sensor infrared permite detectar cuando alguien entra en su campo. Una de las grandes características de este sensor es que es capaz de identificar la luz de noche y día, utilizando así, la energía de vuestros productos LED de una manera más efectiva

Características:
Voltaje: 220 -240V/AC
Frecuencia: 50Hz
Sensibilidad lumínica: 3-2000LUX (adustable)
Temporizador: Min: 10sec±3sec Max: 7min±2min
Potencia nominal: 1200W (bombilla incandescente)(300W bombilla ahorro)
Distancia de detección: 6m max (24º C)
Ángulo de detección: 360°
Temperatura de trabajo: -20C-÷40t
Humedad soportada: <93%RH
Altura de instalación: 2.2-4m
Consumo: 0.45W (encendido) 0.1W (en espera)
Velocidad de detección: 0.6 -1 .5m/s

Función:
Este producto le permitirá ahorrar energía gracias a su sensor de movimiento. De esta forma podrá encender y apagar las luces de forma automática.Su sensor infrared permite detectar cuando alguien entra en su campo. Una de las grandes características de este sensor es que es capaz de identificar la luz de noche y día, utilizando así, la energía de vuestros productos LED de una manera más efectiva.

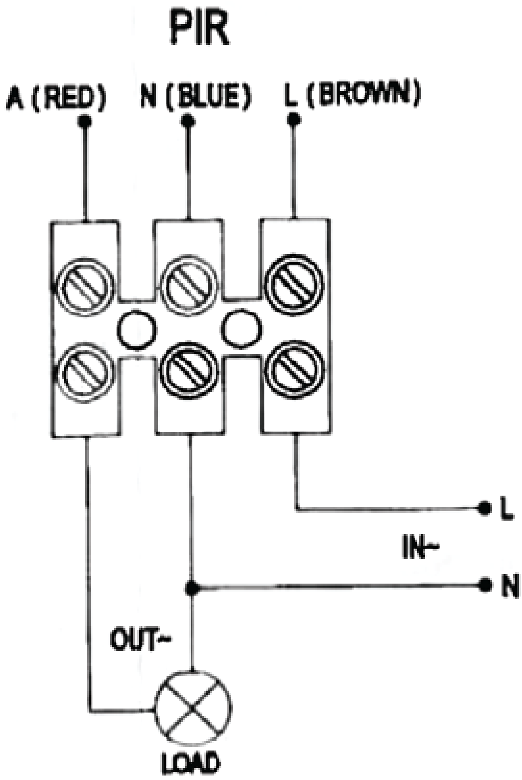
Funciones
Campo de detección: El rango de detección puede ser orientado para mejorar su sensibilidad
Detecta el día y la noche automáticamente. Puede ajustar el sensor de luz ambiente a su gusto: Ajustar al valor SOL para que funcione durante el día y la noche. Ajustar al valor LUNA para que trabaje en condición nocturna (menos de 3 lux ambiente). Para otras condiciones lumínicas pruebe diferentes ajustes.
La función temporizador añade un retraso temporal para el encendido y apagado.
Time-delay is added continually: when it receives the second induction signal after the first inductor, it will compute time once more on the rest of the first time-delay basic (Set time) .
La función temporizador se puede ajustar entre un valor mínimo de 10±3 segundos y un máximo de 8±2 minutos.

Instalación: (Vea diagrama)



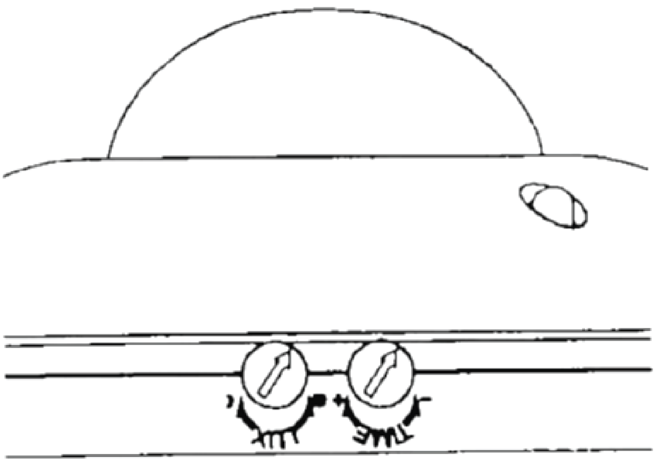
- Apague la corriente
- Gire la tapa inferior hacia su izquierda y retire el anclaje de los cables.
- Afloje de conexión para conectar los cables de corriente al sensor según el diagrama inferior y apriete los tornillos de conexión de vuelta.
  Vuelva a colocar la tapa inferior girándola hacia su derecha..
  Una vez instalado, conecte la corriente y pruebe el sensor.

Diagrama de conexión de cables



Comprobación:

- Apague la corriente.
- Ajuste el selector de tiempo al mínimo y ajuste la selector LUX al máximo.
- Encienda la corriente, espere entre 5 y 30 segundos y compruebe el correcto funcionamiento del sensor..
- Puede ajustar el selector LUX al mínimo y comprobar su correcto funcionamiento tapando el sensor con algún objeto opaco.
- Recuerde: Al probar el sensor durante el día, ajuste el selector LUX al máximo.



Notas

Fácil instalación para electricistas o personas con experiencia
No coloque objetos delante del sensor
No abra la carcasa protectora después de la instalación

Problemas comunes:
No hay corriente:
a. Compruebe la corriente y voltaje.
b. Asegúrese de que la corriente está activa.
c. Asegúrese de que el interruptor de la luz está encendido
d. Asegúrese de que está en las condiciones lumínicas ajustadas en el valor LUX.

La sensibilidad es débil:
a. Asegúrese de que no hay objetos interrumpiendo el sensor
b. Compruebe la luz ambiente.
c. Compruebe que el sensor esté en posición PIR.
d. Compruebe la altura de instalación.
e. Compruebe la orientación del sensor.

El sensor no apaga la luz:
a. Asegúrese de que no hay ningún objeto activando el sensor
b. Compruebe que el temporizador no esté en su valor máximo.
c. Compruebe que la conexión de cables se correspo.
d.Compruebe que no haya fuentes de calor o frío cerca del sensor.

Sensor de presencia por microondas 360º 5.8GHZ

ESPECIFICACIONES DEL PRODUCTO

Alto	42mm
Ancho	72mm
Profundidad	27mm
Peso	43g
Voltaje	220-240V-AC
Grado de estanqueidad	IP20
Material	Plástico
Uso exterior	No
Frecuencia Red	50/60HZ
Potencia Máxima	300W
Ángulo detección	360º
Certificados	CE, ROHS
Garantía	Según garantía legal

DESCRIPCIÓN DEL PRODUCTO

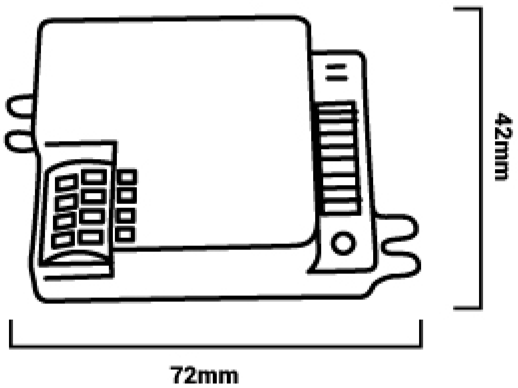
Sensor de presencia por microondas

El **sensor de presencia y de luminosidad** es ideal para un ahorro energético ya que es posible controlar su encendido y apagado de forma eficiente mediante el micro interruptor DIP. Se instala fácilmente y puedes ajustar la distancia de detección (Desde 2 a 10 metros), la luminosidad ambiente (Desde 5L a 300L y con la luz del día) y el tiempo de apagado (Desde 10 segundos hasta 30 minutos). De esta forma puedes controlar cuando se enciende la luminaria y cuando se apagada dependiendo de las necesidades del lugar. Además el sensor tiene un ángulo de detección de **360º** y al ser por microondas puedes instalarlo en **lugares cubiertos** ya que igualmente detectará el movimiento a través de puertas, ventanas o paredes delgados sin materiales metálicos.

El voltaje de entrada es de **220-240V-AC** y el sensor del radar es de **5.8Hz**. La potencia máxima para el sensor es de 1200W para incandescencia y de 300W para las luminarias LED. Posee un canal de entrada para la red eléctrica y un canal de salida para la fuente de luz.

Características del sensor de movimiento:

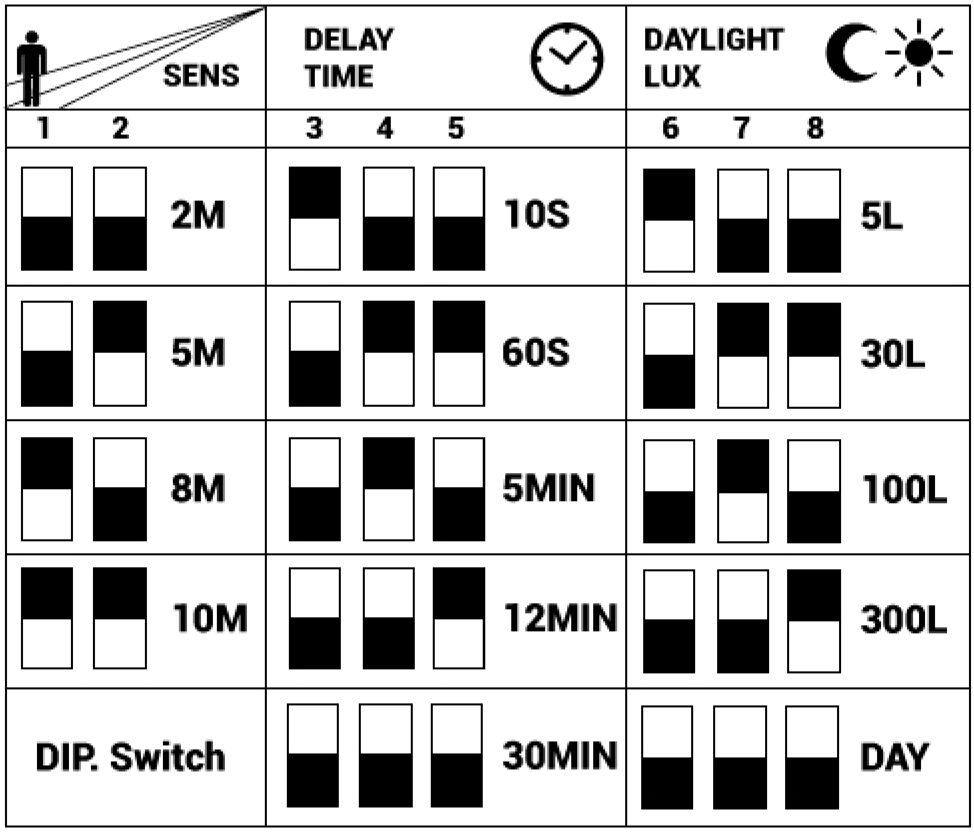
- Sensor Radar: 5.8Hz CW radar, ISM band detection
- Ángulo de detección de 360º
- Opción de ajustar la distancia de detección entre 2m, 5m, 8m y 10m.
- Opción de ajustar el tiempo de apagado en 10s, 60s, 5m, 12m y 30m.
- Opción de ajustar la luz de detección: 5L, 30L, 100L, 300L y con la luz de día
- Potencia Máxima: 300W en LED Y 1200W en incandescentes.
- Clasificación IP: IP20
- Frecuencia: 50-60HZ
- Voltaje: 220 -240 V-AC



Configuración del sensor mediante el micro interruptor DIP:

Con el sensor de movimiento de microondas puedes ajustar la luminosidad, el tiempo de apagado y el alcance de detección con el micro interruptor DIP.

1. El **ajuste del alcance** de detección puede ser de 2M, 5M, 8M o 10M. El alcance deseado puede ser ajustado para evitar la activación indeseada y tener una sensibilidad óptima a la hora de la activación del sensor.
2. El **ajuste del tiempo** puede ser de 10seg, 60seg, 5min, 12min y de 30min. Esto se ajusta para poder definir el tiempo que la luz estará encendida después de la detección. Mientras haya presencia el sensor seguirá trabajando hasta que ya no detecte una presencia.
3. El **ajuste de luminosidad** puede ser de 5L, 30L, 100L, 300L y con la luz del día.



Aplicación del sensor de movimiento y luminosidad:

- Uso exclusivo para colocar en todo tipo de interiores. Entradas de edificios, escaleras, pasillos, aparcamientos y estaciones de servicios entre muchos usos más.
- El sensor puede ser cubierto, ya que la detección es posible a través de puertas, paneles de vidrio o paredes delgadas.

IMÁGENES DEL PRODUCTO